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USER GUIDE to ENGINEERING



Mining and Reclamation in the West

U.S.D.A. FOREST SERVICE
GENERAL TECHNICAL REPORT INT-70
INTERMOUNTAIN FOREST AND RANGE
EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

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**USER GUIDE
TO
ENGINEERING
MINING AND RECLAMATION
IN THE WEST**

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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RESEARCH SUMMARY

The engineer working on mined land must be aware of potential impacts of mining, as well as the techniques available that can help mitigate these impacts. This guide covers major points of concern to the engineer involved in planning for minerals activities including: preliminary site reconnaissance; computer-aided planning tools; transportation systems; minerals exploration and development facilities; geotechnical engineering and mining practices; mass stability; air quality; and reclamation equipment.

Information is presented in a question/rule/discussion format, and includes supporting graphic material, notes on additional sources of information, a glossary, and an index.

ACKNOWLEDGMENTS

The contents of this guide are based on presentations and discussions during the Surface Environment and Mining (SEAM) sponsored Engineering Workshop, April 4-6, 1979, Denver, Colorado. Credit is due all attendees and presenters for their inputs. Those who attended are listed in appendix B. In addition, major contributors are listed under chapter titles as appropriate.

A special note of thanks is extended to William H. Boley, Edwin R. Browning, James J. Butler, Grant Davis, Daniel Hadley, Thomas King, and Dayton Nelson, members of the cadre which planned the workshop. The workshop program coordinator was Edwin R. Browning (SEAM), and the technical advisors were Grant Davis (SEAM) and Dayton Nelson (SEAM).

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INTRODUCTION

MINERAL AND NONMINERAL RESOURCES

An adequate, reliable supply of minerals is essential to the economy and security of the United States, because minerals provide the physical basis for almost all activities of U. S. citizens. While imports can satisfy an important part of the country's minerals demand, they make the U. S. vulnerable to the economic and political decisions of foreign countries. Thus, the mineral deposits within the U. S. are a most important source of this nation's supply.

A substantial portion of the domestic minerals supply presently comes from lands managed by the Federal Government. Federal lands contain a majority of the remaining metallic minerals, as well as major resources of coal, oil shale, geothermal steam, uranium, and oil and gas. These same Federal lands, however, also contain valuable nonmineral resources, including timber, forage, water, wildlife, scenic landforms, and wilderness. The Government's holdings of such resources are now among the most significant in the world.

While it is clearly in the national interest to provide for the identification and production of the mineral resources on Federal land, it is also necessary to provide for a sustained high-level output of the various renewable resources on that land. Thus, the demand for mineral development must be balanced against the demand for renewable resources and the land-management agency's responsibility to reasonably protect the environment affected by mineral-related operations.

MINERALS IN THE LAND-MANAGEMENT PLANNING PROCESS

The Forest Service, as one of the agencies responsible for Federal land management, has a relatively sophisticated planning program for the management of nonmineral resources on land

under its jurisdiction. Historically, however, Forest Service land-management and planning systems have treated minerals as a distinct category outside of the mainstream of the land-management planning process. There are two basic reasons for this separation:

1. The mining and mineral leasing laws have tended to make mineral activity the preferred use on any Federal land open to such activity. The thinking has been that on lands open to mineral activity, mineral development will generally override the designated primary non-mineral uses.

2. Planning for use of the mineral and non-mineral resources is complicated considerably by the difficulties of identifying and estimating the value of mineral resources. Mineral resources can be found only through costly and risky exploration. Therefore, land-management planning has tended to concentrate, at least until a mineral discovery is made, on the surface resource potential of the land.

The long-standing premise that mineral activity is always the most valuable use of a tract of land is increasingly being challenged. Many mineral deposits being discovered today are of lower grade and located at greater depths, and are therefore more expensive to find and mine than the high-grade surface deposits formerly developed. Another significant factor is that non-mineral surface resources are now also considered to be scarce, and their value has increased accordingly.

Hence, when all the mineral and nonmineral values are weighed for a particular proposal at a specific location, the value of the mineral resources may be outweighed by the value of the nonmineral resources. The process of weighing values usually occurs in an Environmental Assessment required by the National Environmental Policy Act of 1969 (NEPA) and is basic to determining the proper mix of uses for any given land area.

Given this situation of mineral and non-mineral values on the same tract of Federal land, decisions as to the proper use of a particular tract of land will always involve balancing the values of mineral and nonmineral resources. If this balancing is to be done in a reasonable manner, adequate information and analysis of all values are needed.

BACKGROUND: THE FORMATION AND MISSION OF SEAM

Realizing the complexity of land-use decisions, the Forest Service chartered the Surface Environment and Mining program (SEAM) in 1973 to coordinate research, development, and application related to land impacts resulting from minerals exploration and development in the West. From 1973 to 1979, SEAM sponsored more than 150 research and development projects. Together, the projects have greatly added to the body of knowledge surrounding the management of land in mineralized areas. (For purposes of this discussion, mineralized areas are defined as those areas that have some potential for mining.)

To get this knowledge to the specialists in the field in a form they could readily use, SEAM brought together researchers from industry, Federal agencies, and the academic community to share their practical knowledge and study results in a series of workshops. The information presented at these workshops is organized into five user guides. Each guide focuses on a specific discipline involved in managing surface resources that may be affected by mineral activities and is written for specialists in these disciplines. The guides will also be of use to land managers, land planners, and other specialists, because many activities related to minerals-area management demand that a variety of skills be applied to achieve an integrated approach.

In addition to the User Guide to Engineering, guides have been written for vegetation, hydrology, soils, and sociology and economics. Cross-referencing among these guides is provided in the index. A handbook for minerals specialists has also been written. A handbook for land managers will provide a general overview of administrative considerations surrounding mineral commodities commonly explored for and de-

veloped on national forest lands administered by the Forest Service. Concurrent with the development of the SEAM user guides, a USDA handbook on visual management related to mining and reclamation, entitled "Mining," is in press as volume 2 of the National Forest Landscape Management Series. A guide for the wildlife specialty is also planned. All guides will be updated periodically to keep them current with research findings.

The purpose of the guides is to help specialists more clearly understand their role in mineral exploration and development activities by outlining some of the major considerations they must address to insure that such activities integrate with land-management plans; that impacts are mitigated to a reasonable degree; and that reclamation meets state-of-the-art performance standards. Perhaps by using these guides as a common starting point, those involved in minerals management can more easily work together toward achieving these common goals: (1) appropriate considerations of mineral values in land-management planning; (2) protection of surface resources during mining activities; (3) reclamation of surface-mined land to a productive use; and (4) mitigation of the adverse effects resulting from minerals development.

HOW TO USE THIS GUIDE

The chapters of this guide cover topics that concern the engineer during both land-management planning and any subsequent minerals activity. Within each chapter, major topics will be addressed in this way:

- **Considerations:** These are the questions the engineer should ask about each topic.
- **Rules:** These general statements answer the questions and direct the engineer toward the type of site-specific information the land manager may need to make decisions. Rules are set in *italic type*.
- **Discussions:** The discussions explain the reasoning behind the rules and in some cases give specific examples of how the rules are applied.
- **Additional Information:** Here the reader will find basic references to further information on the topic discussed.

The aim of this format is to help define the role of the engineer in minerals management.

The guide is not intended to be a "cookbook" on rehabilitation techniques. Rather, it is intended to set up a logical thought process based on a question/answer approach. Such an approach allows for flexibility, eliminates unnecessary data gathering, helps simplify technical decisionmaking, and allows for a systematic documentation of the decisionmaking process. We hope that this organization of material will make the guides equally useful to users in industry, Federal and State agencies, and the academic community.

The role of the Forest Service staff is illustrated in table 1, "Stages of Mineral Exploration and Development Activities," and table 2, "Roles of Forest Service Specialists in Minerals Activities," which follow this introduction. As you will note, the Forest Service engineer will advise, review, and monitor. For example, although design and construction take place during several stages of minerals activities, the engineer reviews these plans when the operating plan is submitted prior to development and, if necessary, suggests revisions to the plan. Then, during operations and reclamation stages, the Forest Service specialist will monitor these activities according to the approved operating plan. In this way, the effects of the development will be managed in a proactive, rather than reactive mode. In other words, rather than reacting to crises, the engineer will be part of the forest's interdisciplinary (ID) team from the time land-management planning begins. Then, if and when mineral activities occur, the team will have foreseen potential problems and will have determined general rehabilitation objectives in advance.

Both land-management planning, in its broader application, and site-specific operational planning for mineral activities on National Forest System lands require the full range of interdisciplinary efforts so that information on

both the mineral and nonmineral values can be presented to the decisionmaker in an integrated manner. The interdisciplinary approach to planning is uniquely suited to giving the best available assessment of the spectrum of opportunities and problems of managing surface resources that may be affected by mineral-related operations and the requirements needed for reasonable protection of nonmineral resources. Soils, vegetation, hydrology, topography, geology, wildlife, climate, and social and economic information are some of the factors that must be considered by the ID team.

Land management and planning must always proceed on the basis of existing information. In the case of mineral resources, this will almost always be difficult because the mineral resources are hidden beneath the surface and information is provided in increments as exploration proceeds. One of the principal goals of Federal land management, therefore, should be to improve such management by obtaining better information about subsurface values and integrating this information into the decisionmaking process.

When using this guide, the reader should keep in mind that, for the most part, the information is concerned with scientific considerations. While other factors, particularly cost and legal constraints, are a crucial part of the planning process, discussion of these aspects is limited here.

One final note: Engineering skills are as much an art as a science. To clarify specific points or to keep up with new developments, readers are urged to contact the workshop participants who contributed to this guide.

Additional Information:

For more information on the mining process, refer to "Anatomy of a Mine," USDA For. Serv. Gen. Tech. Rep. INT-35. 1977. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Table 1. — *Stages of mineral exploration and development activities*¹

Prospecting	Exploration	Feasibility studies/operating plan
<p>A. Administrative Action</p> <p>No administrative action required; however, some evidence of mineralization or a hunch</p> <p>B. Activities</p> <p>Literature search Geological inference Evaluation of existing data Research on rights to land/minerals</p> <p>C. Environmental Impacts</p> <p>Minimal, if any</p> <p>D. Tasks for the Engineer</p> <p>None at this point</p>	<p>A. Administrative Action</p> <p>Permit/Lease Notice of intent from miner (for certain commodities, may also serve as operating plan if there is minimal surface disturbance) Exploration license EA may be necessary See Handbook for Land Managers (in press) for variation within commodities</p> <p>B. Activities</p> <p>More intensive literature search Access road construction On-site testing and evaluation of data—geological, geochemical, geophysical, drilling, sampling, shaft sinking Seismic activity Acquiring land/mineral rights Rehabilitation of exploration impacts Environmental and socioeconomic studies</p> <p>C. Environmental Impacts</p> <p>Roads Drill holes Drill pads Dozer holes Exploration camps</p> <p>D. Tasks for the Engineer</p> <p>Review of plans to reclaim land impacted by exploration Review and assist in engineering aspects of environmental studies</p>	<p>A. Administrative Action</p> <p>Submission of necessary permits (EA, EIS, etc.) and operating plan—see Handbook for Land Managers (in press) for variation within commodities</p> <p>B. Activities</p> <p>Feasibility studies Grade and size of deposit Cost of mining and rehabilitation Market Fiscal Technical studies—mine design Environmental and socioeconomic studies (if not done during exploration) Decision to proceed with development Preparation of operating plan including rehabilitation program and end use Ordering of equipment</p> <p>C. Environmental Impacts</p> <p>Generally none at this stage</p> <p>D. Tasks for the Engineer</p> <p>Review adequacy of operating plan for: Engineering considerations— air pollution transportation facilities surface-mine facilities mine-waste disposal embankments tailings dams and impoundments subsidence Engineering aspects of end use</p>

¹ The various phases have considerable overlap. The material provided for each phase is illustrative, not complete, and considerable variation is found by commodity. The existence of a forest plan is assumed. Tasks (D) are primarily input from a land-management agency's engineer. For purposes of discussion, the terms reclamation and rehabilitation are used interchangeably, and mining includes oil and gas activities.

Development ²	Mining/reclamation	Postmining
<p>A. Administrative Action</p> <p>Approval of necessary operating plan</p>	<p>A. Administrative Action</p> <p>No administrative action required. Mining overlaps with development and reclamation overlaps with mining; reclamation of previously mined areas occurs concurrently with new mining as stipulated in operating plan Any changes in operating plan</p>	<p>A. Administrative Action</p> <p>Release of reclamation bond</p>
<p>B. Activities</p> <p>Securing of financing More extensive testing and definition of the mineral Construction of transportation routes and utilities Construction of mine and processing plant (facilities, water supply, etc.) Construction of waste deposits Continued evaluation of data Change mining plan if necessary</p>	<p>B. Activities</p> <p>Extraction of mineral Processing of mineral Depositing wastes Operation of transportation systems Rehabilitation Monitoring for any changes in biological and physical environment Amend mining and rehabilitation plan if necessary</p>	<p>B. Activities</p> <p>Surface owner manages land after bond release Monitoring for any changes in biological and physical environment Management and maintenance for end-use objective</p>
<p>C. Environmental Impacts</p> <p>Mine Processing plant Waste dumps Transportation and access routes Utilities Increased population resulting from construction</p>	<p>C. Environmental Impacts</p> <p>Impacts directly related to operational aspects of mining; impacts are strongly affected by commodity mined and type of operation</p>	<p>C. Environmental Impacts</p> <p>Directly related to management and maintenance activities</p>
<p>D. Tasks for the Engineer</p> <p>Monitor engineering-related activities for conformance to operating plan Advise on plan revisions when necessary</p>	<p>D. Tasks for the Engineer</p> <p>Advise from an engineering standpoint on release of reclamation bond</p>	<p>D. Tasks for the Engineer</p> <p>Monitor any continued impacts from engineered structures Manage structures for end-use objective</p>

² Development is herein defined as the phase which begins after the right to mine has been established.

Table 2.—*Roles of Forest Service specialists in minerals activities*

	Prospecting	Exploration	Feasibility studies/operating plan
Vegetation specialist	None at this point	Review of plans to reclaim land impacted by exploration Review and assist in vegetation aspects of environmental studies	Review adequacy of operating plan for: Reclamation program — species selection plant materials site preparation planting methods cultural treatments Monitoring/retreatment program for vegetation Vegetation aspects of end use
Soils scientist	None at this point	Review of plans to reclaim land impacted by exploration Review and assist in soils aspects of environmental studies Review soils inventory progress in the mineralized areas; if needed, recommend timely completion or upgrading	Review adequacy of operating plan for: Reclamation Program— soils surveys storage area selection materials handling plans spoils analysis plan spoils treatments spoils surfacing and erosion control Monitoring/retreatment program for soils Soils aspects of end use
Hydrologist	Establish baseline water-quality monitoring as needed according to plan	Review of plans to reclaim land impacted by exploration Review and assist in hydrologic aspects of environmental studies	Review adequacy of operating plan for: Hydrologic considerations— surface water subsurface water snow management roads impoundments mine drainage Hydrologic aspects of end use
Engineer	None at this point	Review of plans to reclaim land impacted by exploration Review and assist in engineering aspects of environmental studies	Review adequacy of operating plan for: Engineering considerations— air pollution transportation facilities surface-mine facilities mine-waste disposal embankments tailings dams and impoundments subsidence Engineering aspects of end use
Economist	Monitor factors which affect supply and demand for minerals Make forecasts of supply and demand Predict probability	Analyze costs and benefits of alternative exploration methods Participate with the sociologist in identification of existing and emerging issues	Provide expertise in environmental analysis process: issue identification decision criteria cost/benefit analysis of alternatives tradeoff and opportunity-cost evaluations Analyze effects of development on: demand for surface resources human behavioral patterns community economics
Sociologist	Identify the basic social/cultural descriptors of the affected communities Note current trends	Assist in structuring public involvement plan for appropriate: issue identification issue analysis mitigation action Identify critical trigger points from a social perspective	Provide expertise in environmental analysis process: decision criteria issue identification Analyze effects of development on the cultural and political community Consider effects of alternative plans on social well-being

Development	Mining/reclamation	Postmining
Monitor vegetation impacts and activities for conformance to operating plan. Advise on plan revisions when necessary	Monitor vegetation impacts and activities for conformance to operating plan. Advise on plan revisions when necessary Advise from a vegetation standpoint on release of reclamation bond	Monitor any continued impacts on vegetation Manage vegetation for end-use objective
Monitor impacts on soils Monitor soils-related activities for conformance to operating plan. Advise on plan revisions when necessary	Monitor soils impacts and activities for conformance to operating plan. Advise on plan revisions when necessary Advise from a soils standpoint on release of reclamation bond	Monitor any continued impacts on soils Manage soils for end-use objective
Monitor impacts on hydrology	Monitor impacts on hydrology and hydrologic aspects of rehabilitation program Have hydrologic input into release of reclamation bond	Monitor any continued impacts on hydrology Manage hydrology for end-use objective
Monitor engineering-related activities for conformance to operating plan Advise on plan revisions when necessary	Advise from an engineering standpoint on release of reclamation bond	Monitor any continued impacts from engineered structures Manage structures for end-use objective
Record costs Monitor economic changes	Record costs Monitor economic changes	Monitor to determine accuracy of predictions for future use
Monitor Record changes Identify areas of individual or group stress relating to mineral activity and make recommendations to mitigate effects	Monitor Record changes	Monitor and record critical changes to establish new baseline situation

Chapter 1

PRELIMINARY SITE RECONNAISSANCE

Chapter Organizer: William Boley

Major Contributor: William Boley

During the development of the forest plan, broad decisions affecting all the resources on national forest lands will be made, as well as decisions about what activities should take place on a given piece of land. Before such allocation decisions are made, site-specific information may be needed. Depending on the type of mining and the laws that control a specific mineral, the location of a mining or processing operation may be influenced, and in some cases dictated, by the land-management agency. In many cases, a minerals operation is influenced by road access, and the complete process may be changed because of site and access conditions. During preliminary site reconnaissance, the Forest Service engineer, as a member of, or contributor to, the ID team, will be involved in collecting such site-specific information.

What is the purpose of preliminary site reconnaissance in relation to mining?

Preliminary site reconnaissance will help to assess the quality and quantity of the effects of minerals activities on national forest lands. This information will be useful in offsetting the short amount of time the Forest Service has to respond to a mineral company's request for a minerals lease or an exploration permit.

Discussion:

Although site reconnaissance can be conducted at any time, from the first stages of planning on Forest Service land until a minerals operation is approved, preliminary reconnaissance is the survey or inspection that takes place before decisions are made that affect land allocation for a particular activity. It is the link between land-management planning and project commitment, and most of the critical issues the

Forest Service engineer will identify during this process will be site specific.

Preliminary site reconnaissance is an interdisciplinary planning job, during which the engineer and other specialists must determine not only what effects mining will have on Forest Service land, but also what measures must be taken to coordinate minerals activities with other resource uses and with resource protection. While the precise location of mineral deposits probably cannot be determined at this point, general information should be obtainable, based on the geology of the area. Site investigation should provide a better understanding of where arterial and collector roads may best be located, and whether or not short-term facilities¹ will be necessary if mineral exploration occurs. This type of planning is important, because unlike other resource activities on forest lands, the Forest Service does not control when minerals development will take place. Such planning allows time for advance evaluation of impacts before a permit is requested. It also allows consideration of alternative approaches for a project.

What occurs during preliminary site reconnaissance?

During reconnaissance, the engineer and other members of the ID team may investigate such items as terrain, slope, drainage crossings, land ownership, hydrology, vegetation, and stability.

Discussion:

During reconnaissance, the Forest Service engineer, sometimes in conjunction with industry, will consider arterial and collector road

¹A short-term facility is a road that will cease to exist after the objectives for which it was developed are accomplished. Its useful life is less than 5 years. This term covers all roads on Forest Service lands that were previously called temporary.

location, and prescribe types of surveys, construction control—and in the case of a short-term road—prescribe rehabilitation and reclamation methods. At this point no commitments have been made about leasing, and the engineer

is merely investigating whether the land is suitable for minerals development, what the effects of minerals development might be, and whether these effects can be mitigated.

Chapter 2

COMPUTER-AIDED PLANNING TOOLS

Chapter Organizer: Dale Frost

Major Contributors: Dale Frost, David Gibson, Thomas King, Thomas Lehman, M. Douglas Scott

Currently, computer systems are being developed that can be used by land managers, Government regulatory agencies, and mining companies to design mine facilities and plan land reclamation. Methods are being tested for processing surface and subsurface data in a digital form that a computer can quickly manipulate and display. Generally, computer systems have visual display and simulation capabilities which, by using topographic, and subsurface and surface data such as timber type, can depict what a proposed mine development will look like before any actual construction work begins. These computer tools can provide significant planning help for a forest land manager and engineer. This chapter discusses two such processes, LANDFORM and SEAMPLAN, which are being developed by the Forest Service in cooperation with various other organizations.

In addition to these processes, many other computerized techniques are available. They include techniques for traffic-network analysis, land-use evaluation, display systems, and supply-demand analysis. Individuals involved in minerals development should review available computer techniques with forest and regional staff to secure the right tool for the job being conducted.

THE LANDFORM PROCESS

What is LANDFORM?

LANDFORM is an acronym for Land Analysis and Display FOR Management. It is a computer-aided system of planning and designing minerals development and reclamation.

Discussion:

LANDFORM is a series of integrated computer programs designed to take surface and subsurface data gathered in accordance with prescribed criteria, manipulate and perform various calculations on these data, and produce information, plots, and computations that are useful both for land-management planning and for engineering design. The accuracy of the output is directly dependent on the quality and accuracy of the input. The system is designed to provide a statistical expression of how well the digital terrain model prepared as part of this system can interpolate the elevation of independently determined test points. This allows the user to decide if the data file has sufficient resolution for the planned project.

What are the benefits of using LANDFORM?

LANDFORM brings together digital modeling techniques, engineering design programs, and information display techniques into a single, integrated process. This process will help land managers, industry, and the public identify the costs and benefits of a development proposal in a more timely and effective manner.

Discussion:

The use of the digital terrain model with certain of the system programs enables the user to take physical features or characteristics from any map with an established coordinate system and plot them onto other maps or photographs. The programs also generate design quantities from basic input such as horizontal and vertical alignment and section templates.

Some other advantages of using a systematic computer-aided process are:

- Reduction of planning and design costs.
- Ability to examine and evaluate a greater number of alternative actions.
- Ability to provide more comprehensive

plans and designs with more satisfactory consideration of all resources.

- Depiction and simulation of proposed actions making them more easily visualized and understood by planners and the public.
- Improved analysis and coordination of various development operations with resulting efficiency and reduced costs.

How is LANDFORM organized?

LANDFORM is divided into three basic phases: Data Gathering and Organization, Information Display, and Designs and Plans.

Discussion:

Phase I — Data Gathering and Organization. There are various methods used to collect data for the first phase of LANDFORM. In one method, digital models are built using techniques of gathering surface and subsurface data from aerial photography and geologic exploration methods. Terrain data may be gathered in different ways. The Mahan method involves developing a digital terrain model from a stereo pair of aerial photographs. This is produced by digitizing individual points along drainages, ridgelines, and general form lines.

Another method involves using data collected by the U. S. Geological Survey as a byproduct of the agency's orthophoto production process. These data, which are derived from 1:80,000 scale photography, are of intermediate level (40-ft contour) accuracy. This level is suitable for planning where fine resolution is not essential, and would be an inexpensive method of rapidly and economically obtaining data for general forest land-management planning.

Yet another method is collecting data directly from a contour map. The collection process can be done using the principles of the Mahan method or by digitizing along contour lines.

In addition to surface information, subsurface data can be gathered from drill hole logs or by other geological techniques. From these data, subsurface information such as ore bodies, faults, and other geologic structures can be displayed. Both surface and subsurface information can then be interrelated to other resource information for consideration in mine design.

A key requirement of any computer-aided modeling system is the ability to store large quantities of data (the digital model) and provide an efficient means of retrieving selected portions of that data for developing designs or displays. LANDFORM is structured so that all entering data are transformed to a uniform coordinate system. These data are then referenced so that specific information can be readily located without searching the entire data bank.

Phase II — Information Display. During phase two, the visual display puts the data into a form easily understood by the various audiences that will use LANDFORM. Existing and proposed landforms can be portrayed in perspective with basic products such as contour, grid, slope, and aspect. In addition, alternative action designs can be generated and plotted. This would include displaying land lines, pit designs, transportation designs, and waste-disposal areas in the perspective of vertical or oblique photographs as well as in two- and three-dimensional plots.

Phase III — Designs and Plans. In phase three, designs are generated by engineering programs using surface and subsurface digital models. This information can be used for a variety of products, such as computing quantity of overburden or waste material, defining both quantity and quality of mineral deposits, and generating earthwork quantities for alternative transportation facility locations. These outputs are helpful to designers and planners for analyzing specific effects of an action prior to actually starting the action on the ground.

How can LANDFORM be applied on a mining project?

A technology transfer process will get the system and its application to potential users.

Discussion:

In order to transfer the understanding and use of LANDFORM to those who can benefit from it, the process is being documented in two handbooks: The User's and Operator's Manual and the Programmer's Manual (in press). These documents are the framework for a training program that can be directed toward the Forest Service, other Federal and State agencies, and industry.

Further developments and refinements beyond the initial release of the program are antici-

pated. Initial application has been oriented to supporting the decisionmaking process regarding mineral areas. As a result of an increased concern for environmental protection, and resulting legislation, careful and complete planning of mineral development has become mandatory. Comprehensive planning is especially important because mining not only requires a significant investment but also produces rapid and significant changes in the physical, biological, social, and economic structure of a community. Timely decisions are required in order to effectively deal with these changes.

The long-range goal of LANDFORM is to help the land manager, whether State, Federal, or private, do a better and more comprehensive job of planning for development and reclamation. The possibilities of using computer systems for gathering and displaying information can lead to more informed and objective decisions on a wide range of activities involving changes in landform.

What is the current status of LANDFORM?

Most of the programs presently available in LANDFORM have had limited testing and were able to be operated by November 1979. In the future, there undoubtedly will be changes, additions, enhancements, and corrections to the manuals and the programs.

Additional Information:

For further information about the LANDFORM process, contact Thomas King, The LANDFORM Project, Engineering Staff Group, USDA Forest Service, 324 25th St., Ogden, UT 84401.

THE SEAMPLAN PROCESS

What is SEAMPLAN?

SEAMPLAN is a minicomputer-based mine and reclamation system for surface coal mines. The process can be used to plan and design mining operations, as well as to monitor the operations once production is underway.

Discussion:

By integrating programs and research results from a variety of sources, and by utilizing state-of-the-art interactive computer graphics technology, SEAMPLAN enables planners to evolve

mine plans to meet stated production and cost objectives, while considering tradeoffs between productivity and environmental protection. This system may also be used as a tool to designate areas unsuitable for mining, and to determine the most feasible postmining land use. The system is capable of expansion as new technology and information pertaining to mining, reclamation, and environmental impacts become available.

How is SEAMPLAN organized?

SEAMPLAN consists of five software modules implemented on a minicomputer. The modules are defined as the data management module, the graphics module, the production analysis module, the reclamation planning module, and the impact analysis module. The data management and graphics modules do not, however, exist as separate entities. Instead, data access and graphic displays are an integral part of the other modules.

Discussion:

The data management module. Basic input to the SEAMPLAN system consists of four main types:

1. Core or drill-hole data, which provide a description of the physical and chemical conditions under which mining might take place. Such information might include the depth of overburden, the depth of coal, and the various qualities and characteristics of each.

2. A second type of information input is related to the production and capital requirements of the operation. Such information might include required tons/yr, minimum required rate of return, and the projected selling price of coal.

3. Restrictions with respect to environmental protection, such as those specified by the law or by management objectives. These restrictions could place constraints on such things as the basic type of mining operation, the method of spoiling overburden, and reclamation methods.

4. Site data, such as climate, soils, and hydrologic conditions. These data would be used to estimate environmental impacts, to develop reclamation strategies, and to plan postmining land use.

After the basic input is fed into the system, a large array of computational and mapping routines is available to the user. Displays of the ge-

ology, stratigraphy, and various properties of the overburden can be made in the form of three-dimensional perspectives, contour plots, fence diagrams, bar charts, and various other graphical modes. The primary purpose of this part of the system is to allow the user to recall, manipulate, and display information to aid in designing the production and reclamation operations of the mine.

The production analysis module. Once the user has obtained the various maps and computational summaries necessary, a mine plan can be developed and analyzed by using the production analysis module. This module consists of three design levels. The mine planning process begins at level two, pit design, because the greatest cost of a Western surface-mining dragline operation is removal of overburden. At this level the user can evaluate a number of stripping techniques and objective functions. After the pit and dragline operations have been designed, the user can employ either level one or three. At level one, all the auxiliary operations that support overburden removal are analyzed. Other operations are specified according to the production rate of the dragline. Included among these operations are topsoil removal, drilling and blasting, coal loading and hauling, coal preparation, reclamation, general support operations, and cash flow analyses and reports. Level three provides a detailed evaluation of the overburden removal operation. For any given location in the mine, mining method, and specified dragline sequence, this level can be employed to perform a swing-by-swing simulation. While such detail may not be required for production planning, it is necessary in order to predict environmental responses.

The reclamation module. The reclamation module, CLAIM, consists of four main product subsystems: FEASI, TECON, OPUSE, and GRADE. The FEASI subsystem evaluates approximately 75 environmental data inputs, and ranks the relative environmental feasibility of returning the area to each of the five main land-use options, which are: cropland, native vegetation, wildlife habitat, recreation, and high human use.

TECON is a system that evaluates the local environmental conditions, then prints a list of recommended reclamation techniques, with

costs, for each of the five land-use options. OPUSE combines the results of FEASI and TECON, to produce a ranking of the five land uses from the most optimal choice to the least.

The GRADE program is a part of the TECON subsystem, but also can be operated separately to determine grading costs for both dragline and truck and shovel mines. This system allows the operator to specify the basic mine configuration, as well as describe what the topography should look like after reclamation. Then the program will calculate the total cost/acre for grading. The CLAIM system is designed to interact with the mine production module, so that tradeoffs between reclamation requirements and productivity needs can be made.

The impact analysis module. After the production plan has been specified, this module is used to predict various environmental responses, such as wind and water erosion, characteristics of ground and surface waters, subsidence, and wildlife. If some of these responses are unacceptable, the user can backtrack through the production and reclamation modules and design an alternative plan.

The operations monitoring module. This module can be used to monitor activity once operations have begun. Because features of a particular site may be different than the first projections, the economics of the market may change, equipment and methods may improve, the original plan may need to be modified and updated. This module may also be used by industry and regulatory agencies to review the progress of individual mines, or all mines by ownership and location.

What is the current status of SEAMPLAN?

Most of the programs presently available in SEAMPLAN have had limited testing and were able to be operated by November 1979. In the future, there undoubtedly will be changes, additions, enhancements, and corrections to the programs.

Additional Information:

For more information on SEAMPLAN, contact Edward R. Burroughs, Jr., Forestry Sciences Laboratory, P. O. Box 1376, Bozeman, MT 58715.

Chapter 3

TRANSPORTATION SYSTEMS: PLANNING, DEVELOPMENT, OPERATIONS

Chapter Organizers: William Boley, William Martin

Major Contributors: Robert Hadley, Ira Hatch, Ronald Hayden, William Martin

One of the goals of the Forest Service is to plan, develop, and operate a network of transportation systems on national forest lands that will provide for user safety, convenience, and efficiency, while accomplishing land- and resource-management goals. These transportation systems include roads, trails, railroads, waterways, pipelines, slurry lines, conveyors, tramways, airports, and power transmission lines. The Forest Service engineer is a key person in coordinating these facilities so that they complement each other and form an integrated system that meets the overall goals of the forest plan.

As part of the forest plan, land managers and Forest Service engineers will evaluate the current road system and will identify needed improvements to the forest's arterial and a portion of the collector road systems. Different transportation systems for various land- and resource-management alternatives are also considered. Transportation planning considerations during the forest plan should include, to the extent possible, minerals-management access needs.

Transportation planning must also be done at the project plan level. Project plans, such as mining operating plans, will identify those specific transportation facilities needed to carry out project activities and will examine the relationship of these facilities to the long-range transportation needs established in the forest plan. As an example, at the time an operating plan is filed, the engineer needs to examine such items as road standards, location corridors, maintenance requirements, traffic control, and reclamation procedures. Although roads are generally the prevalent form of facility needed for a project,

other types of facilities must also be considered. This chapter looks at transportation systems through three phases: planning, development, and operations. Planning and development will generally be done during premining activities; operations occur during all mining phases.

TRANSPORTATION PLANNING

Why is it difficult for the Forest Service to include minerals management in long-range transportation planning?

Planning for minerals management is difficult because the minerals resources are underground, the extent of the minerals is generally unknown, and the Forest Service doesn't control their development. This is not the case with renewable-resource management, since those resources are visible, are generally quantifiable, and the Forest Service controls them.

Discussion:

Because it is difficult for the Forest Service to predict what transportation facilities will be needed for minerals exploration, development, and operations, Forest Service personnel usually find themselves in the position of having to react to proposed minerals activities. This situation is especially acute at the exploration stage, when road permits are requested on very short notice. Mining companies often can't predict the extent of their operations until some exploration work has taken place. They are also reluctant to divulge proprietary information about the nature and scope of their prospecting intentions and discoveries. Such safeguarding of information prevents the Forest Service from knowing what types of traffic and loads to expect. Thus, road requests must be reviewed in the context of anticipated damage and the potential of the road to serve renewable resources.

What can be done to make access planning for minerals activities easier?

The problems involved in predicting transportation needs for minerals activities can be diminished if the lead time for road permits is increased, the nature and scope of the mineral discovery are known, and the Forest Service has a long-range transportation plan for the area.

Discussion:

Although mining companies hesitate to discuss their prospecting intentions or discoveries, Forest Service geologists who have some knowledge of the nature and scope of planned minerals activities can help the engineer predict the related transportation requirements. Also, if the Forest Service has a long-range transportation plan for the area, a judgment can be made about how well the roads needed for minerals management will complement these planned long-term needs.

What control does the Forest Service have over minerals exploration access?

While the Forest Service generally cannot deny a company access to certain areas when exploring for minerals, it can specify the types (short-term or long-term) and standards of roads the company must use.

Additional Information:

For more information, refer to Section 7730 of the Forest Service Manual and Section 36, Subsection 212 of the Code of Federal Regulations.

What is the best choice for access during minerals exploration?

During minerals exploration, the most desirable choice for access is to utilize an existing road system, even though it may have to be upgraded to accommodate exploration equipment.

Discussion:

Before determining whether an existing road system can be used for exploration activities, the forest engineer will need to know the type of equipment the mining company has, the volume of additional traffic and when it will occur, and the current use of the road. The engineer will need to consider such factors as whether or not the road is open to public use; what type of

vehicles presently use it; whether use of the road by the public and other commercial traffic conflict with exploration usage; what traffic control and maintenance levels are necessary; and, if needed, whether materials are available for improving the road surface. When setting the road maintenance level, it will be necessary to determine if the road should be watered, if it should be bladed more frequently than before exploration, and if drainage structures such as culverts will need to be upgraded to support heavier loads.

After exploration, the original maintenance level for the road can once again apply, unless exploration activity has changed the road's use pattern.

What occurs during planning for a mine transportation system?

During planning for a mining transportation system, the forest engineer will review the mine operating plan to see if the proponent gives specific locations for all roads; uses existing roads wherever possible; plans (as much as possible) new access routes on the same locations where the Forest Service plans to develop permanent roads; and uses geometric alignment criteria that are based on the intended standards for these roads.

Discussion:

The land manager must supply the operator with any specific requirements or limitations imposed by the land-management plan. The operator, the land manager, and the U. S. Geological Survey representative must reach agreement on drilling or development locations. In addition, the mining operator should supply information about the type of mineral to be mined, the type of operation (whether the mine will be surface or underground), and the type and location of facilities (roads, railroads, pipelines) required.

The operating plan for the proposed minerals operation should include: (1) a map that shows proposed and existing facilities; and (2) descriptions of their characteristics.

The review of transport and access needs for the mine should include:

- **Location corridor.** Where will the road be built? (Where possible, facilities that were used for exploration should also be used during production.)

- **Functional class.** Will the road be short term or permanent, and if permanent, will it be arterial, collector, or local?

- **Vehicle design.** What kinds of equipment will travel on the road?

- **Traffic volume design.** How much traffic must the road carry? Public, Forest Service, and mining traffic should all be considered.

- **Speed design.** At what speeds will the traffic on this road travel?

- **Use duration.** Will the road be used year-round or just seasonally?

- **Measures to mitigate environmental damage.** Will there be environmental damage, how much, and what can be done to offset any damage?

- **Survey, design, and staking requirements.** What controls are required to assure that the road is completed as planned?

- **Surface type.** Will the road have an asphalt or an aggregate surface?

- **Suitability for public use.** Will the public be able to use the road after the mining company no longer needs it? If so, who will maintain it? If not, how will it be used, or will it be put to bed and reclaimed?

What design standards are used for analyzing transportation facilities?

Two types of design standards are used for analyzing transportation facilities. Geometric standards deal with dimensions such as alignment, grades, widths, sight distances, and clearances. Structural standards apply to such features as thickness, composition of materials, construction methods, and load-carrying capacities.

Discussion:

Selection of design standards must be based on the vehicles or equipment to be used and their operating characteristics. Many of the vehicles used in minerals operations are longer, wider, heavier, and have a longer wheel base than those used for other purposes. These variations must be considered when setting design standards. The requirements of the equipment will generally dictate minimum standards; standards above this minimum should be justified by a formal analysis.

Short-term facilities should be designed so that they can be obliterated after they have served their purpose. Long-term facilities should

be designed to serve the projected maximum traffic or use requirements that might occur in the design life.

When must a mining operator reconstruct an existing road on forest lands?

The mining operator must reconstruct existing roads if the additional minerals traffic cannot be accommodated safely and/or if it will cause road damage.

Discussion:

If additional traffic cannot be safely accommodated on an existing road, it might be possible for the mining operator to use the road during nonpeak traffic hours. Another option might be to reconstruct the road, perhaps changing it from a single-lane to a double-lane road. Reconstruction costs will be borne by the operator.

To determine whether reconstruction is needed, several factors should be considered (most of this information must be supplied by the minerals operator):

- User safety.
- Seasonal and daily fluctuation of traffic flow.
- Estimated peak-hour traffic.
- Distribution of vehicles by type and weight.
- Directional distribution of traffic.
- Economics.

TRANSPORTATION DEVELOPMENT

How is a mining-related transportation facility actually developed?

Development of a transportation facility involves survey, design, and construction.

Discussion:

The land manager, based on information supplied by the Forest Service engineer, should specify the survey standards for each facility. The survey standards should be based on land and resource values, design standards, construction specifications and controls, terrain, and costs. The land manager also specifies which method of design will be used. Prior to design, the mining company's engineer should conduct field investigations to obtain the subsurface data necessary for designing stable cut and fill slopes,

adequate foundations, and surface or pavement structures. The types of tests and the methodology used in conducting these tests should be consistent with the nature of the materials and the design situation. The land manager can specify the amount of field investigation and testing required for each facility.

Construction of roads on National Forest System lands is governed by the "Forest Service General Provisions and Standard Specifications for Construction of Roads and Bridges—1979."² Some standard specifications exist for other facilities, such as water and sewer lines. Where there are no standard specifications, such as for conveyor systems, project specifications will have to be developed. Drawings and specifications for transportation projects will be reviewed and approved by the land manager based on information received from the engineer. Construction should be monitored to make sure it meets specifications. The land manager is responsible for final inspection and approval of each project.

TRANSPORTATION OPERATIONS

What is the role of the Forest Service during operation of a transportation facility?

The Forest Service is responsible for monitoring, evaluating, regulating, and controlling transportation facilities; administering any cooperative transportation programs and activities; and maintaining certain transportation facilities.

Discussion:

State traffic codes generally apply to Forest Service roads that are open to public travel. In some cases, such as where off-highway loads are allowed, Federal regulations for traffic control and road management apply when State traffic codes are inadequate or inapplicable.

It is necessary to apply for permission to use Forest Service roads for commercial purposes. Road permits may be made conditional on sharing maintenance costs. Mining operators are responsible for maintenance commensurate with their use of Forest Service roads, and they are responsible for *all* maintenance on roads where they have exclusive use through a special-use permit. An approved operating plan is not usually required to use existing Forest Service roads, as long as traffic safety is maintained and hauling does not damage government property or resources. An operator must receive advance permission to use an existing road that has been closed by, or with the approval of, the Forest Service. Permission to use such closed roads may be based on an approved operating plan; if no operating plan is required, a special authorization must be obtained from the Forest Service. After abandonment, all short-term roads must be rehabilitated.

²Engineering Manual, Section 7720-100. USDA For. Serv.

Chapter 4

SURFACE FACILITIES FOR MINERALS EXPLORATION AND DEVELOPMENT

Chapter Organizer: William Boley

Major Contributors: Phillip Bursk, William Fiant, Ira Hatch, Omer Humble, David Morris, Dayton Nelson

As a member of the interdisciplinary team, the Forest Service engineer will be involved in determining the effects of minerals exploration and development on forest-system lands. Environmental damage can result not only from exploration methods and equipment, but also from transportation systems and other facilities needed to conduct this activity. Thus, prior to exploration, the engineer and other staff specialists will need to work closely with industry to set standards (when appropriate), establish continuity with on-going and future projects, insure that specific projects meet the Forest Service's long-range goals, and determine appropriate methods and technology to use for each project.

If exploration results in minerals development, the location of the operation can sometimes be influenced or dictated by the land-management agency, depending on the type of mining involved and the laws that control the mineral. Road access can also determine the location of an operation.

When minerals development does occur, one of the Forest Service engineer's functions will be to review the company's operating plan for the design and construction aspects of the operation's surface facilities, and provide the land manager with an assessment. During this process the engineer will work with other government agencies, such as the Mine Safety and Health Administration, the Office of Surface Mining, and the U. S. Geological Survey.

MINERALS EXPLORATION

When a minerals company does exploration work, what activities occur?

During exploration, a minerals company will conduct on-site testing and evaluate data obtained through the use of geology, geochemistry, geophysics, drilling, sampling, shaft sinking, mapping, surveying, and seismic recording. For many of these activities, short-term roads will be necessary, and such roads must be rehabilitated when they are no longer needed. See figures 1 and 2 for examples of exploration equipment.

Discussion:

Minerals exploration activities may vary from relatively simple projects involving no surface disturbance, to complex, high-density programs that disturb 100 percent of the surface land area. These complex programs may take detailed planning and rehabilitation, because, in some cases, exploration can have an even greater impact on the land surface than minerals development.

When minerals exploration takes place on forest lands, what will the major-engineering concerns be?

When a minerals company begins exploration work on forest-system lands, it is important to consider how long the activity will take to complete, the time of year during which the activity will occur, the kinds of equipment the company will use, the facilities it will need, how the equipment and facilities will affect the environment and what rehabilitation measures will be necessary. (See figures 3 and 4 for examples of rehabilitation measures.) The Forest Service engineer has basically the same responsibilities for minerals facilities as he does for other special-use developments.

Discussion:

Standards need to be tailored for each site, based on environmental values that need to be protected, the type of equipment that will be used, and the facilities that will be built.



Figure 1. Three tractor-mounted vibroseis machines gathering seismic data during oil and gas exploration.



Figure 2. Portable and vehicle-mounted drills used during oil and gas exploration.



Figure 3. A dry, wildcat hole being restored. Dozer is leveling the site and filling in the mud pit. The drill hole is plugged and monumented.



Figure 4. Wildcat drill site after the first catch of native grass. Only the drill hole shows.

What types of facilities may be constructed during exploration?

Facilities connected with exploration activities are usually drill pads, pit tanks, camp sites, water facilities, and transportation systems.

Discussion:

Each of these facilities should be designed and constructed to avoid permanent adverse impacts on the environment. The engineer should also check with local zoning and health authorities, to see if any special requirements, such as a septic tank, need to be included in the project plans. If a company uses existing roads for exploration activities, it will be important to find out the types of vehicles the company will be operating, what kind of maintenance and traffic control the road will require, and who will fund and do the maintenance. (For a more detailed discussion on roads for minerals exploration, see chapter 3.)

Additional Information:

For more information on oil and gas exploration and production, refer to:

"A Primer of Oil Well Drilling," The Uni-

versity of Texas at Austin. Third Edition, 1970.

"Primer of Oil and Gas Production," Production Department, American Petroleum Institute, 300 Currigan Tower, Dallas, TX 75201.

MINERALS DEVELOPMENT

What is the role of the Forest Service in relation to minerals development facilities?

The Forest Service should monitor the design and construction of the facilities related to minerals development, to make sure these facilities conform to the company's operating plan. Activities should be coordinated with other appropriate agencies such as the Office of Surface Mining and the U. S. Geological Survey, or the equivalent State or Federal reclamation agency to avoid duplicating efforts. Monitoring during operations should insure appropriate construction of new or expanded facilities, and maintenance of existing facilities.

Discussion:

The layout and design of minerals development facilities is essentially a premining activity.



Figure 5. Typical surface coal-mine layout with a generating plant, transportation facilities, and a town.

Eighty or ninety percent of the money spent on facilities will be spent before any ore is mined. The remainder will be spent during the life of the operation for maintenance and for new facilities needed for expansion.

Construction standards for surface facilities are often prescribed by law. The Mine Safety and Health Administration, for example, regulates the design of bathhouses and magazines. (See figures 5-7 for examples of surface facilities related to mining.)

Detailed design and planning for surface facilities is usually accomplished either by a company's in-house engineer or by consulting engineers. Construction is generally done by subcontractors, except for some large firms that maintain their own construction capabilities. The responsibility for maintaining surface facilities rests with the company.

What determines the facilities that will be included in a minerals operation?

Surface facilities for a minerals operation are determined by the geometry of the deposit, topography, water availability, size of the operation, climate, location of the transportation

system, the mining method, and beneficiation requirements.

Discussion:

The geometry of the deposit determines whether a mine will be surface or underground, which is the first step in assessing what surface facilities are required. Rugged topography, such as that associated with much of the underground coal mining on forest-system lands in the West, has a profound effect on the layout of the facilities. In many cases, topography will dictate where the facilities will be located. As the topography becomes more gentle, greater flexibility exists in site selection.

Water is necessary for dust control, fire prevention, personal hygiene, and for ore preparation and mining itself. Pump houses, reservoirs, and pipelines other than those related to oil and gas are all affected by water availability. The size of the operation directly affects the size of facilities such as the office, the bathhouse, and the warehouse. Climate is also a factor. In some cases a severe winter climate might make it necessary to build air-heating units into the mine ventilation system. Harsh weather might also

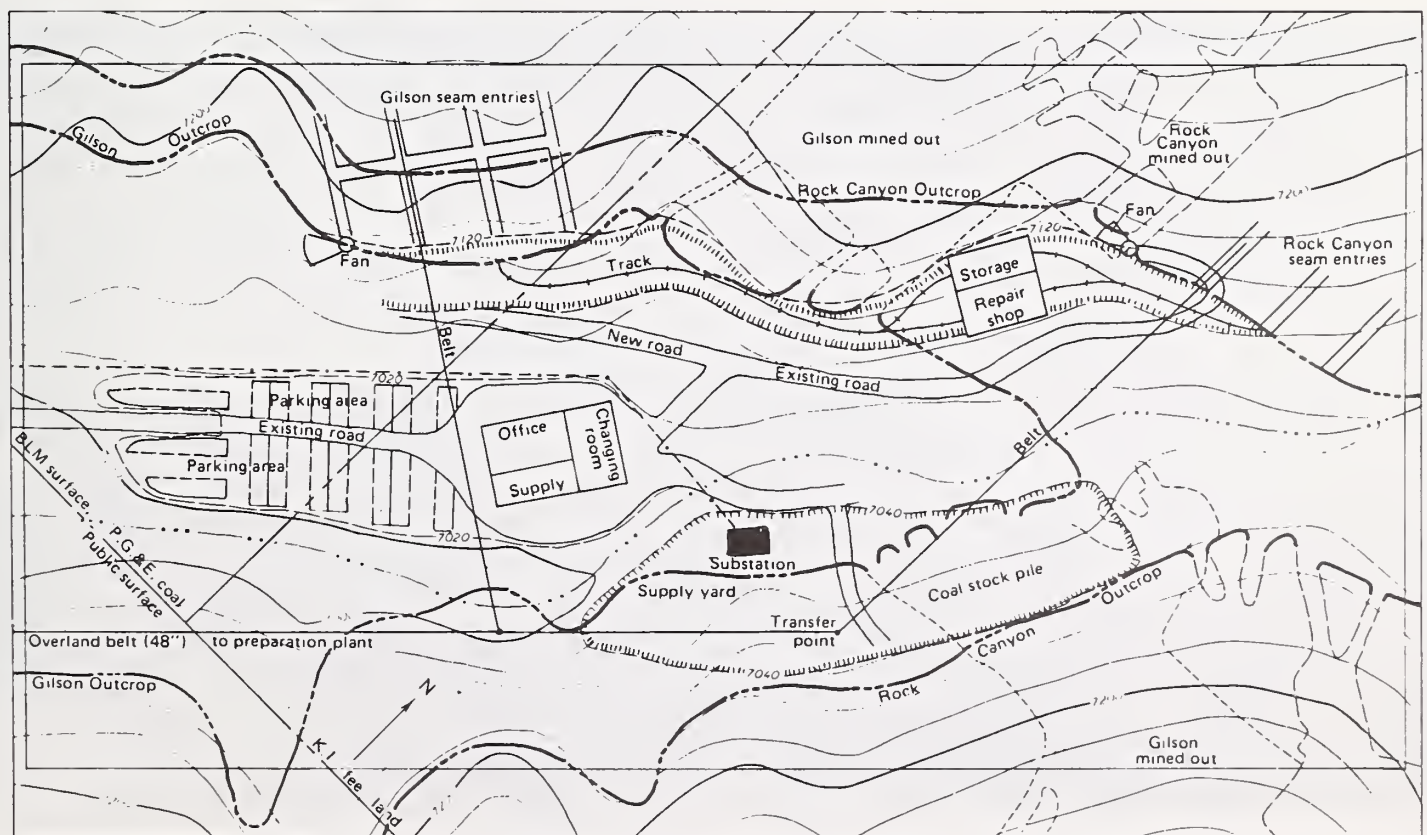


Figure 6. Surface facility layout of a typical Utah underground coal mine. (David Morris, John T. Boyd Co)

cause a surface mining operation to maintain enclosed bays to protect equipment not in use.

In coal operations, rail haulage is an important consideration. Unit-train loadout facilities require a large amount of space in the form of either a rail loop or a dead-end spur.

The mining method will affect the size and design of supply storage facilities, shops, and the electrical distribution system. Mineral beneficiation influences the actual facilities associated with the plant, the water supply, disposal system, and the design of the water disposal facilities.

Do most mineral developments have the same types of facilities?

Some facilities are common to both surface and underground mines, as well as oil and gas operations. Other facilities, however, are generally associated with one method of mining or the other, and some facilities are unique to oil and gas developments.

Discussion:

Some facilities generally associated with all minerals developments are:

- **Essential.** Office, bathhouse/changehouse, powerlines, electrical substation, parking area,

mineral storage area, loading facility, fresh water supply/storage, equipment supply/storage area, drainage and sedimentation system (includes ponds, dams), access road, topsoil stockpile, mineral beneficiation plant, refuse disposal area, rotary breaker/crushing station, explosives storage, warehouse/shop, laboratory, water treatment plant, haul roads, railroad/truck scales, sewage-treatment plant.

- **Optional.** Diesel generator, conveyor belt system, guard house, visitors' center, air strip, helicopter pad, training center, housing/new town.

Some facilities generally associated with an underground mine are: fanhouse, shaft with headframe, rock dump bin, rock dust storage, degasification plant for coal mining.

Some facilities generally associated with a surface mine are: diesel fuel storage, truck wash, tire storage, oil and grease house, equipment parking area, truck dump, spoils dumps, bridges, culverts, reclamation test plots.

Some facilities generally associated with an oil and gas development are: crushers, screens, flotation units, storage tanks, drilling rigs, heater units, separators, containment dikes, salt-water injection pipelines.



Figure 7. Typical surface facilities of a phosphate beneficiation plant.

Chapter 5

GEOTECHNICAL ENGINEERING AND MINING PRACTICES

Chapter Organizer: Bruce Vandre

Major Contributors: Loren Anderson, Bruce Vandre

The practice of geotechnical engineering essentially involves the design aspects of slope stability, settlement, earth pressures, bearing capacity, seepage control, and erosion. These factors are major considerations when developing a mine because some geotechnical concerns—for example, mine-waste dumps—have a poor history in terms of stability and environmental effects. Moreover, the consequences of slope failure are not only highly visible, they can also be catastrophic.

This chapter deals with the total geotechnical engineering role from the standpoints of both industry and the Forest Service. Although the geotechnical engineer working for industry will prepare the actual plan for a minerals development, the Forest Service engineer will review a company's operating plan and advise the land manager of the geotechnical considerations, as well as propose design guidelines. The Forest Service alone will not be responsible for all geotechnical review, but will interact with other agencies such as the Mine Safety and Health Administration, the Office of Surface Mining, the U. S. Bureau of Mines, and the U. S. Geological Survey.

GEOTECHNICAL ENGINEERING

What is the geotechnical engineer's main job?

A major part of the geotechnical engineer's job is to determine the physical engineering properties of earth materials.

Discussion:

Unlike the structural engineer, who can specify the compressive strength of concrete and the

stress/strain properties of steel, the geotechnical engineer must determine the shear strength and other important physical properties of soil and rock. The geotechnical engineer must also decide how these properties change with time, with loading conditions, with moisture conditions, and with the method of compaction. All of these factors will significantly affect the shear strength, the compressibility, and the permeability of the soil. Consequently, after the site investigation and laboratory testing program, experience and judgment are major factors in determining the engineering properties of soil and rock.

What types of disciplines does geotechnical engineering encompass?

Geotechnical engineering is concerned with geology, soil mechanics, and rock mechanics.

Discussion:

Solving difficult geotechnical engineering problems often requires a team approach, involving interaction between engineering geologists and engineers specializing in soil mechanics and/or rock mechanics. In addition to understanding the basic principles of these disciplines, a knowledge of precedents is essential for the successful practice of geotechnical engineering.

What kinds of evaluations and recommendations do geotechnical engineers make?

Geotechnical engineers evaluate slope stability, settlement, earth pressures, bearing capacity, and seepage and erosion, and then recommend design criteria considering the specified performance requirements.

Discussion:

Geotechnical engineers are concerned with the stability of natural and man-made slopes; the settlement of buildings and earth embankments; earth pressures in the design of retaining struc-

tures; bearing capacity in foundation design; seepage control in dam construction; and ground-water movement and erosion from highway embankments, dam surfaces, and spoils dumps. Geotechnical recommendations must consider such specific design or performance requirements as a minimum degree of safety against shear failure or a limiting structural deformation. These requirements may be dictated by structural engineering, hydraulic engineering, economics, policy, or even convention. Conventional or standard safety factors against shear failure are frequently used in foundation design and the design of earth-dam-embankment slopes.

What does the geotechnical engineering process entail?

The geotechnical engineering approach is to: Define the project concept; perform project site reconnaissance; develop a working hypothesis of subsurface conditions; test the hypothesis through field investigation and laboratory tests; develop a model for analysis; evaluate alternatives; make specific recommendations; prepare plans and specifications; provide construction inspection and consultation; and obtain performance feedback.

Discussion:

After the geotechnical engineer working with industry determines the purpose of the subsurface investigation, the next step in the process is project site reconnaissance. This involves a trip to the field to look over the project site, as well as researching any geologic or subsurface investigations that have already been done for the area. On the basis of this information, the engineer will develop a working hypothesis of subsurface conditions, in order to plan the subsurface investigation in terms of the number and type of borings to make, what kind of equipment to use, what kinds of samples to take and how many, and what kind of laboratory tests to run.

Because field conditions generally indicate a nonhomogenous condition with many minute strata of various soil types, it is necessary to develop a simplified model for analysis. After the model has been analyzed, the geotechnical engineer will evaluate the alternatives, including economic factors, and make specific recommendations. The job of the geotechnical engi-

neer in industry should not stop here; he should also be involved in preparing plans and specifications, and in providing construction inspection and consultation. In order to evaluate the adequacy of recommendations and designs, performance feedback should be obtained from all projects—not just those involved in failures.

How can geotechnical engineering be applied to mining?

Geotechnical engineering is applied to mining primarily in the design of excavation slopes, waste embankments, and tailings dams.

Discussion:

Applying geotechnical engineering to mining is essentially using established technology rather than developing new technology, since the methods of geotechnical investigation and analysis used in highway or dam design can also be applied to mine design. Design considerations such as slope safety or construction methods, however, will frequently differ between highways or dams and mines.

When planning and designing mine-waste embankments, abandonment is an important consideration, because mine embankments should be maintenance free at this stage. While highway embankments and dams should also require minimum or no maintenance, the opportunity for maintenance does exist.

MINING PRACTICES

What is the key relationship of geotechnical engineering to the economics of surface mining?

A prerequisite for understanding surface-mining economics is knowledge of the stripping ratio (the number of units of unpayable material that must be mined to expose one unit of ore).

Discussion:

One specific stripping ratio is the break-even stripping ratio. It is determined by forming an equation that contains the recoverable value/ton of ore, minus production costs/ton of ore, divided by the stripping costs. An economic stripping ratio is determined by subtracting desired profits as well as production costs.

A point may be reached where the cost of stripping makes surface mining more expensive

than underground mining. Generally, geotechnical engineering decisions greatly influence the stripping costs, which vary with different minerals. For example, the stripping ratio for phosphate is about 6 yd³ of waste for 1 yd³ of ore. For coal, particularly when using excavating equipment with capacities of 180-220 yd³/pass, the possible economic stripping ratio might be as high as 20-40 yd³ of overburden per yd³ of ore. With copper, a common economic stripping ratio would be about 2 yd³ of overburden for 1 yd³ of ore. These variations in stripping ratios are explained by the differences in commodity prices, ore grades, and mining methods.

What geotechnical factors influence the selection of surface-mining methods?

The selection of surface-mining methods is controlled by surface topography, the geometric delineation of ore or mineral deposits, and environmental considerations. The first two items determine the stripping ratio.

Discussion:

With flat terrain and flat, thin deposits, access is gained with a box cut, and continued with succeeding parallel cuts. The overburden is cast to the side previously excavated. The dimensions of the excavation slot are primarily determined by the reach and capabilities of the excavating equipment.

Steep terrain, but flat, thin deposits, require a contour strip mine—that is, starting with a bench and excavating it around the hill. The cutoff for mining is determined by the economic stripping ratio, which determines the height of the high wall. Historically, with this method, overburden was disposed of either by pushing it off to the side in piles, by pushing it off parallel to the existing slope, or, sometimes, by pushing it off at a flatter slope. Now, because of environmental concerns, the mining company tries to

control spillage from excavation, so in the initial box cut a berm is left to prevent material from spilling over the side. Contour stripping can also be used if the minerals occur in multiseams.

With steep terrain and thin deposits that are fairly close to the ground surface, a method called mountain-top removal may be used. Again, access is gained with a box cut. The first material excavated from the box cut generally has to be disposed of at a different location, possibly as valley fill. After the initial cut the overburden is placed as backfill in the mined-out area. Additional offsite disposal of overburden is required because of the swell in volume between the original ground and the fill. With this method there is no high wall to reclaim.

Thin, flat deposits and strip mining are characteristic of coal mining. Other types of deposits that are surface mined generally fall into the category of open-pit mining. Usually open-pit mining is circular in plan and involves steeply dipping or thick deposits, which are excavated in benches, both for stability and for access. In deep excavations, such as in copper mining, knowing the slope stability from geotechnical analysis can be very important economically, because a difference of 1 or 2 degrees in the slope could mean a considerable difference in stripping volume.

Additional Information:

For more information about geotechnical aspects of mining, refer to "Procedures Recommended for Overburden and Hydrologic Studies of Surface Mines, Final Report, Part I, SEAM Thunder Basin Study," (Draft), by James Barrett, Paul Deutsch, Frank G. Ethridge, William T. Franklin, Robert D. Heil, David B. McWhorter, and Daniel Youngberg. Colo. State Univ. and USDA For. Serv., Douglas, Wyo. December 1978.

Chapter 6

MASS STABILITY AND MINING

Chapter Organizer: Bruce Vandre

Major Contributors: Michal Bukovansky, Richard Dunrud, Frederick Thompson, Roy Soderberg, Bruce Vandre

In mine design, one of the geotechnical engineer's prime concerns is mass stability as it relates to rock slopes, waste-disposal embankments, tailings areas, and subsidence in underground mines. Mass stability is critical to the minerals company from an economic standpoint. For example, when excavating an open-pit or a strip mine, the mining engineer will try to make the slopes as steep as possible without incurring slope failure, because one degree of difference in height could mean a significant difference in excavation costs. Steepening the slope embankments can also frequently reduce costs for waste disposal; however, slope failures can damage adjacent facilities.

Mass stability is also critical to the Forest Service, but for different reasons. Slope failures in mining can cause severe environmental damage, as well as pose a threat to human life.

EXCAVATION AND SURFACE MINING

In the preliminary design stage, what decisions will a mining company make?

At this stage, mining companies will decide what mining method to use, the approximate steepness of the slopes, and make basic decisions on benches and haulage roads.

Discussion:

At this point, the mining company will decide whether or not to use open-pit or strip mining, as well as the shape of the mine. The company will also develop a working idea of slope steepness, since this factor will make an important difference economically.

What should occur during the mining company's geotechnical investigation?

The mining company's geotechnical engineer, generally an outside consultant, will do mapping, drilling, and testing.

Discussion:

The geotechnical consultant will begin the investigation by mapping outcrops, testing the types of rocks and soils in the area, and drilling to learn the properties of the overburden for construction of the plant and tailings area. The geotechnical engineer will also keep logs of geophysical tests to verify the composition of the rocks and soils, and, if ground water is present, will install observation wells. Testing will then be conducted in order to estimate the physical properties of the rocks and soils.

What is a stability safety factor?

Essentially, a safety factor is a ratio of resisting forces to driving forces. Several common methods can be used to calculate a safety factor, and thus obtain some numerical index of stability.

Discussion:

If the safety factor is greater than one, the resisting forces are larger than the driving forces and the slope or slide is stable. If the safety factor is just equal to one, equilibrium exists. If the safety factor is less than one, the resisting forces are smaller than the driving forces, and the slope or slide is unstable and will probably move. Simple rock-slope design charts are available to help evaluate safety factors.

Additional Information:

For more information on safety factors, refer to "Rock Slope Engineering," by E. Hoek and J. N. Bray. Institute of Mining and Metallurgy, London, 1974.

Are any risks involved in slope design?

Yes, uncertainty exists about the reliability of the stability analysis. In soil and rock me-

chanics, there is no way to exactly determine physical properties.

Discussion:

Theoretically, if the safety factor is equal to one, the slope should be stable. Because of uncertainties in data, analysis, and knowledge of geologic conditions, however, the geotechnical engineer uses safety factors greater than 1.0 for design. For civil engineering structures, such as highway cuts, the safety factor usually starts at 1.5 and can go to 2.0 and higher. The mining engineer, however, cannot afford to excavate slopes that appear highly safe, because the costs of excavation would be too great. Economically, it may be advantageous to risk the chance of a small slide.

What are the main types of rock-slope failures?

In rock, there are three main types of slope failures: planar failures, curved failures, and combined failures.

Discussion:

Planar failures happen along planes of weakness, such as a fault, joint, or bedding surface, and typically occur in hardrock materials. Curved failures occur in rock that is weathered and has comparatively uniform strength. Combined failures, which usually occur in horizontally bedded deposits, happen most often in coal and uranium mining.

How can slides be stabilized?

Slides can be stabilized by excavating the slope entirely; excavating the upper portion or loading the lower portion; or installing drainage, buttresses, piles, retaining walls, or anchors.

Discussion:

When an open-pit slope fails, one solution is to excavate the entire slide. If the slide is large in size, it may be feasible to excavate only the upper portion, thus decreasing the magnitude of the driving forces. Stability can sometimes be achieved by loading the lower portion of the slide and increasing the magnitude of the resisting forces. Another possibility is to combine both methods and excavate the upper portion of the slide and load the lower portion.

Most slides are related to ground or surface water; therefore, if the water is removed there is a good chance that the slide will stabilize. One of the most popular and economical ways to achieve this in rock is to install horizontal drains. Drainage lowers the ground-water level to a safe position behind the slope of the open pit, and with horizontal drains, drainage is accomplished by gravity. The miner excavates individual benches, and installs a series of horizontal drains, which are inclined holes lined with casing. This is usually done on several levels. The water is carried away from the pit, the walls are dry, and there is a good chance that the slide will stabilize. To monitor the effectiveness of the drainage system, piezometers should be installed. Drainage prior to excavation will generally result in steeper design slopes. Tunnels can also serve as drains, and are used in a number of large, open-pit hardrock mines.

Buttresses, piles, and retaining walls and anchors, also increase the resisting forces and stabilize slides, but these methods are not widely used in open-pit mining.

How can stability problems be detected and quantified?

A good method of detecting and quantifying stability problems is proper use of instrumentation and monitoring.

Discussion:

The company's geotechnical engineer will usually ask the mining company to install a means of monitoring a slope and measuring deformations. The method used may be as simple as surveying. Other possible methods are:

- A shear strip, which is installed in a vertical hole and shears off if the slide moves. With a simple electronic readout, the depth of the failure plane can be estimated.

- A tiltmeter, which measures ground-surface inclination. It is set on the crest of the benches of the pit, and should be checked at least once a month. If the slope is moving, the inclination measurement will change.

- An inclinometer, which measures changes of inclination in a vertical hole.

- An extensometer, which can be used to measure deformation changes in either vertical or horizontal holes.

MINE-WASTE DISPOSAL EMBANKMENTS

What is a mine-waste dump?

A mine-waste dump is a waste-disposal embankment consisting of earth and rock. These embankments, which are usually located on side hills or in valleys, are not water-impounding structures.

Discussion:

Mine-waste disposal embankments generally have little utility in themselves—they are designed primarily to avoid adverse impacts on the environment. The stability and general performance of these dumps should accommodate reclamation and enable future land use compatible with the surrounding area. These embankments should not endanger life, property, or natural resources. Upon abandonment, these embankments should be maintenance free.

Historically, how have mine-waste embankments performed?

Mine-waste embankments have a history of poor performance. It is estimated that 10 to 20 percent of the mine-waste embankments in the United States and Canada have experienced significant slope-stability problems.

Discussion:

Landslides shoot tongues of debris into streams and onto adjacent lands that otherwise would remain untouched by the direct influence of mining. Slope failures also disrupt the vegetative cover established on reclaimed slopes and increase the erosion potential. Another major problem common to waste embankments is settlement. Cracks in the embankment surface occur and massive sections drop. Surface water drainage is disrupted and the embankment stability may become threatened. Settlement can make land unsuitable for use as pasturage or for cultural development. Waste embankments can also change water quality and disrupt flow patterns. With coal waste there is the added concern of fire from spontaneous combustion. Many of these embankment problems occur 10 to 20 years or more after construction. Most of the waste embankments that have failed in the past, however, have not been engineered according to geotechnical practice.

What types of slope failures are common for waste embankments?

Common types of waste-embankment slope failures are curved-arc failures, shallow flow slides and foundation failures.

Discussion:

- **Curved-arc failures.** Damage is usually limited to the immediate slope area. Warning signs of these failures are tension cracks at the top of the slope and bulging at the toe. Common causes of curved-arc failures are: The embankment height may be too great or the slope ratio may be too steep for the soil shear strength; the toe of the slope is either undercut or it becomes saturated.

- **Shallow flow slides.** These occur during heavy rainfalls or high snowmelt, and their depth is commonly less than 5 ft. Shallow flow slides are highly fluid and mobile, and often disrupt areas below the slope. They may occur without warning, cause erosion, disturb vegetation, and hinder reclamation activities.

- **Foundation failures.** These occur when the slope wedge moves out along weak foundation soils. The most severe damage is to the immediate slope vicinity. Foundation failures generally are caused by the end-dumping method of fill placement, which rapidly loads the foundation soils. Foundation failure is progressive in the direction of dumping and may extend beyond the planned limits of the embankment.

What are important site-selection considerations for waste embankments?

The location of a mine-waste embankment is determined primarily by economics, topography, foundation conditions, and future ore reserves.

Discussion:

From an economic standpoint, the shorter the haul distance, and the closer the top of the waste embankment to the excavation elevation, the cheaper the operating costs will be. Thus, there is a strong economic motivation to locate the waste embankment as near to the excavation as possible.

Flat topography is also desirable for waste-embankment placement, because a flat surface

reduces stability problems and provides greater storage capacity for fill material. Generally, when fill material is placed on a slope greater than 20 degrees (35 percent or 3:1), the foundation and preparation requirements become critical. Embankments placed on slopes steeper than 27 degrees (50 percent or 2:1) frequently are unstable.

The presence of cohesive soils and shallow ground water in the foundation may limit the embankment height or restrict the placement method to thin layers. Also, to safeguard stability, drainage measures within the embankment will be required at ground-water discharge locations. Finally, it is important not to cover up future reserves, because what is not mineable ore today could be mineable tomorrow.

What steps are usually involved in the design of waste embankments?

Usually the procedure for design will involve:

- *Making a field reconnaissance of the general site area.*
- *Making a preliminary layout and comparing the areal extent, height, and economics of alternative disposal locations capable of storing the intended mine output of waste solids.*
- *Selecting the most promising site, making a geologic appraisal, and establishing a program of foundation and materials investigation.*
- *Analyzing surface-water diversion requirements.*
- *Analyzing embankment geometry requirements.*
- *Analyzing internal drainage requirements.*
- *Preparing construction drawings and specifications that identify placement procedures.*
- *Verifying embankment material properties used for design during construction.*

Are waste embankments instrumented and monitored like mine excavations?

Generally, the same methods of instrumentation and monitoring used for excavation slopes also apply to waste embankments; however, less monitoring is done for embankments.

Discussion:

Embankments usually have higher design safety factors than excavation slopes, thus their performance is less questionable. For monitoring information to be useful, adverse performance

needs to be detected during embankment construction, because remedial measures become difficult after construction is completed. Embankment foundations may be instrumental to control filling rates.

Additional Information:

For more information on waste embankments refer to:

"Recommended Bibliography on Geotechnical Practice for the Design of Non-Water Impounding Solid Waste Mine Dumps," by Bruce C. Vandre. USDA For. Serv., Intermt. Reg. Off. Rep., February, 1979. Ogden, Utah.

TAILINGS DAMS AND IMPOUNDMENTS

What should be considered when choosing tailings sites?

Tailings sites are waste-disposal areas for the residue that remains after a mineral or ore has been processed at a mill. When choosing tailings sites it is important to consider whether the mine will be underground or open pit, what the daily mill tonnage will be, and what environmental impacts may occur on the site.

Discussion:

During site exploration the engineer must make detailed topographic maps, determine the geology of the potential tailings site, core drill for potential economic mineralization in the pond area, and map the surface soil conditions. The engineer must also determine the strength of the foundation; map potential borrow areas for dam building and sample the soil for physical properties; determine the depth to ground water, the number of springs in the area, and the existence of buried talus slopes that could pipe water through the dam; and measure the drainage area above the tailings site.

If the mine is underground, it will be necessary to determine whether any of the tailings will be used for underground fill, leaving the finer material to be impounded in the pond. The size of the tailings area is then determined by the daily mill tonnage minus this fill material. About 35 acres should be allowed for each

1,000 tons of daily capacity. The area should also be divided into two separate ponds for safety and ease of handling.

If there are several possible sites, the one with the least potential environmental effects should be chosen, such as an area hidden from main roads or nearby communities by trees or mountains. While every effort should be made to keep dust from blowing off the tailings area, this does occur, and thus should be a consideration during site selection.

What can be done to minimize environmental impacts from the tailings area?

To minimize environmental impacts, surface runoff from large areas above the tailings site should be diverted around, rather than through, the tailings pond and water-reclaim system. All the water that goes into the tailings pond should be held in a closed system and sent to the mill's reclaim-water reservoir for reuse. The starter dike, which is constructed of borrow material, should be planted with trees and grass as soon as possible.

Discussion:

Some rain and snow will naturally enter the tailings pond, and should be treated before being returned to natural drainage. A diversion ditch could greatly reduce the amount of water needing treatment, and is also a safety feature that could prevent the dam's overtopping.

Drainage from beneath the tailings pond usually goes back to the mill's reclaim-water reservoir. All water going into the tailings pond, such as slurry water, precipitation, mine drainage, and surface drainage should be contained in a closed system and sent to the mill for reuse. Any surplus should be treated, if necessary, and returned to drainage.

Usually the starter dike is easy to revegetate, except in arid areas where irrigation is necessary. The tailings alone are more difficult to replant, because they require more care, fertilizer, and moisture than natural soil does. Some tailings that are high in sulfides oxidize and become so acidic that they are impossible to vegetate unless a foot or more of topsoil is placed on the tailings after mining is completed. Sulfide tailings are possibly the most difficult material to reclaim because soil cover is generally unavailable and even when obtainable, placement costs are high.

What are the various types of tailings dams?

Basically there are two types of tailings dams: the water-reservoir type of dam used for toxic materials, such as cyanide from a gold mill; and common tailings dams, which have many variations. The design of a common tailings dam will be determined by the physical properties of the material being impounded.

Discussion:

The design of a tailings area will be influenced by tonnage, screen analysis, pulp density of the pond, site geology, hydrology, soil classification and physical properties, soil permeabilities, and tailings mineralogy. Tailings ponds should be designed so that all water can be reclaimed. It will be important for the engineer to carefully review the tailings-site design plans. Many mining companies hire outside consultants to design their tailings areas, but some consulting firms are designing tailings areas without previous experience in this field.

When are drains for the bottom of tailings ponds required?

Whether or not drains are necessary on the bottom of a tailings pond is determined by the purpose and nature of the pond and the geology of the area.

Discussion:

When drains are required on the bottom of a tailings pond, it is a good practice to cover them completely with cyclone underflow if the sand produced is clean. (A cyclone is a machine that spins water, removes coarse material, and then sends both the fines and the water upstream.) This sand should be spigoted off the starter dam at its natural slope, since this slope will be steeper than the slope of the unclassified tailings (fig. 8). Thus, when the tailings are placed in the pond, slime will not settle on top of the drains and clog them. Clean sand from a cyclone is attainable only when a relatively low pulp density (small amounts of solids to large amounts of water) is fed to the cyclone.

What controls the safety factor in tailings ponds?

The safety factor for tailings ponds is primarily controlled by the phreatic water line,

which is the top of the free-water surface within the body of a dam or tailings embankment.

Discussion:

The static safety factor, or the safety factor when conditions produce no sudden jarring movements, should be 1.5 during operation of the tailings pond and higher after the pond has been abandoned for a few years and the water pool has been lowered or eliminated. If the water in the embankments is kept low, the downstream slope kept flat (3:1 overall maximum), and the dike and beach compacted above critical density so that liquefaction does not take place, the safety factor should be 1.5 or higher. Constructing the downstream face at a 4:1 (25 percent or 14°) slope will increase the safety factor and will also help with reclamation, since plants take root and hold the soil much more easily on flatter slopes.

How is construction control for a tailings site achieved?

During construction, a competent inspector, either a mining company employee or a company consultant, should be on the job full-time to make sure that all construction is carried out according to design.

Discussion:

The inspector should make sure that:

- The dam foundation and the drain area are cleared of all vegetation, peat bogs, and unstable soil.
- The foundation is compacted and prepared.
- Either pipe drains with gravel or protective filter cloths or blanket or strip drains with adequate clean gravel and protective filters are installed.
- Borrow is properly placed: coarser, more pervious material on the downstream side, and



Figure 8. Spigoting around periphery of tailings embankment. (Roy L. Soderberg, U. S. Bureau of Mines)

finer, more impervious material on the upstream side.

- Proper moisture for optimum compaction is available, and laboratory facilities are available to check for moisture and density control.

- There is special compaction through the starter dam for pipes with seep-rings.

What types of instrumentation and monitoring are common for tailings dams?

Two types of piezometers are recommended for monitoring tailings dams—the open well and the pneumatic. The open-well piezometer is the most common, is least expensive, lasts the longest, and is the easiest to read. One disadvantage is that it has a slow response time when used in low-permeability materials such as clay.

Discussion:

Piezometers are necessary to measure the effectiveness of the drains to insure that water is not building up behind the starter dam. High water indicates the drains are not functioning properly, and corrective measures must be taken to prevent potential instability.

With open-well piezometers, if an increase in head occurs the water in the well must fill the entire tube to that height to register the true head. The pneumatic piezometer registers pressure only, so the response time is nearly instantaneous. In high-permeability areas, such as coarse beach sands, open-well piezometers should register the response with only a short lag time.

Pneumatic piezometers should be placed beneath the starter-dam foundation and just upstream from the upstream toe of the starter dam. If a hollow stem auger is available, it might be easier to place the piezometers after the starter dam is completed, which will protect the lines from damage during construction. At the same time, open-well piezometers should be placed by each pneumatic piezometer, and could be placed in the same hole. This protects against the failure of either one. Pneumatic piezometers can be placed on the natural soil upstream from the toe with the lead lines up beside the header pipe for protection. After water in the dam is high enough, an open well can be placed beside each of the pneumatics.

Open wells should be placed on the downstream face periodically as the height increases,

to continuously monitor the water. The water depth should be measured monthly and plotted on a cross-section of the dam to see if it conforms to design plans.

When a dam reaches 100 ft or more, a slope-indicator casing can be placed in the dam to measure movement. Measurements should be made several times a year. Monuments can also be placed on the berm in a line of site to measure both horizontal and vertical movement. Some movement is inevitable, but a stable embankment will have only a small and steady movement.

How is reclaim water within the pond controlled?

Reclaim water is controlled through the use of decant lines and towers, barge pumps, movable wheel-mounted pumps, and siphons (fig. 9).

Discussion:

The decant line for a small operation can be a simple 10-inch, Schedule 40 steel pipe, which is laid on top of the ground from below the starter dam to the upstream side, to the clear-water pool. As the height of the dam increases, the line is extended to keep it in the clear water.

In larger operations, reinforced concrete decant lines should be designed to withstand the total weight of the sand above the lines. Decants remove water from the pond even though a rain-storm might cause power failure for several days. Even if the water overflows the spillway of the holding pond below the tailings dam, this is preferable to overtopping the tailings dam and washing tailings into the watershed.

Towers should be reinforced concrete and can be freestanding, or, if the area is steep, they can incline along the side of the valley. There is some danger that freestanding towers could be pushed over by a subsurface slide of slime or large ice sheets.

Under proper conditions, barge pumps are less expensive to build and operate than decant lines. It is difficult, however, to keep the barge out of the mud when the pond is in a flat area and the tailings are very fine. Also, the clear-water pool tends to be shallow, causing the pump to suck up slimes. In steep terrain, with coarser material, the barge pump is ideal. Then the water pool is generally deeper, and as the dam height increases, the pumping head de-

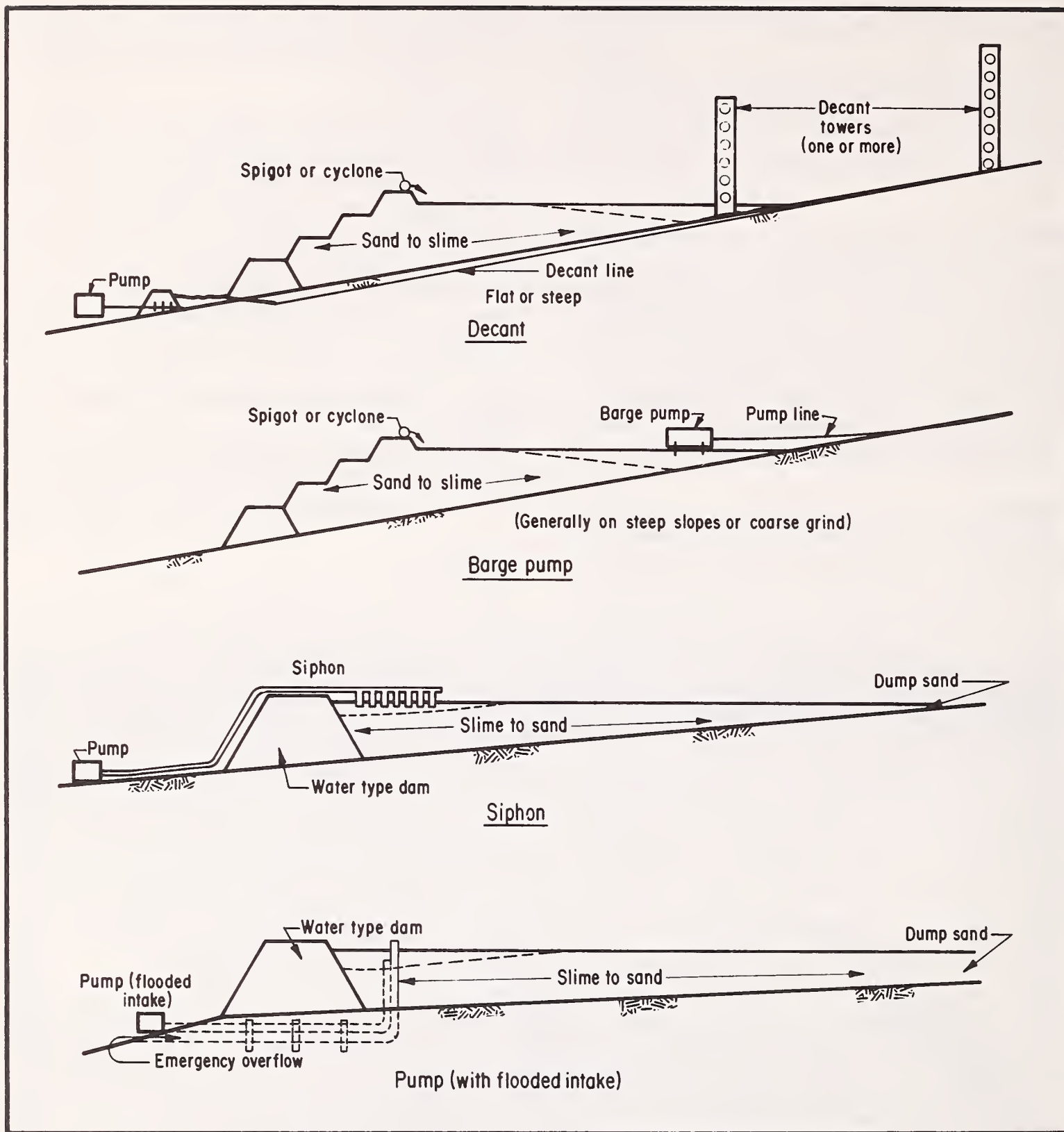


Figure 9. Schematic of decant, barge pump, siphon, and pump with flooded intake. (Roy L. Soderberg, U. S. Bureau of Mines)

creases, thereby using less power. The disadvantage is that in the case of a severe rainstorm and a power failure, the tailings pond might overtop if it cannot retain all the flood water. In such a situation, a diversion ditch is necessary when a large upstream area drains directly into the tailings pond.

Movable wheel-mounted pumps may be placed at the clear-water pool on the natural soil within the tailings area. As the water rises they can be moved upstream. They have the same advantages and disadvantages as the barge pump, but because they need long suction lines, they are not as efficient.

Siphons are not recommended for regular tailings dams because the water they use must be near the dam, which creates instability. They can be used for water-reservoir type tailings dams only.

What are common causes of tailings dams failures?

Tailings dams and ponds fail because of seismic shock and/or poor construction, design, or operation.

Discussion:

The typical tailings dam failure is the curved-arc failure, which results from saturated embankments. Failure occurs when the driving force is greater than the resisting force of the soil. While water does not reduce or change the shear angle, it can reduce the cohesion to zero and add weight to the driving force to increase the chance of failure.

Computer programs are available that can calculate the safety factor of an embankment.

When should a tailings area be reclaimed?

Tailings areas should be designed so that they can be reclaimed in stages. Tailings ponds that have not been designed for staged reclamation should be reclaimed either when they are full or when they are no longer needed for the mining operation.

Additional Information:

For more information on tailings areas, refer to "Design Guide for Metal and Non-Metal Tailings Disposal," by Richard A. Busch and Roy Soderberg. U. S. Bureau of Mines Information Circular 8755. 1977.

SUBSIDENCE IN UNDERGROUND MINING

What factors potentially influence subsidence?

Subsidence is a local lowering of surface land caused by the collapse of rock and soil into an underground void. Subsidence, which can result in stability failures such as landslides and mine-roof cave-ins, is influenced by geologic structure, faults, joints, ground water, and the lithology of the overburden. The thickness, area, and number of ore seams mined determine the size of the void and the extent of subsidence.

Discussion:

Even if subsidence is contained in a relatively small area underground, it may have widespread impacts on surface lands. Thus, the unknowns involved in predicting subsidence, particularly where mining methods employed leave potentially unstable mine voids, make reclamation and land-use planning difficult for many years. Even when relatively safe land-use options can be determined, controlling surface land use is still a problem, because of conflicts between the rights of minerals and surface owners, as well as the increasing demand for use of surface land.

What is the geotechnical engineer's role regarding subsidence?

In order to evaluate potential subsidence, it is necessary to have a firm geotechnical base about the strength of the ore, the mine roof, the mine floor, the present condition of the materials, and what can happen should the materials become weathered or saturated over long periods of time.

Discussion:

Subsidence can be controlled to some degree by the method of mining. There is less potential for subsidence, for example, when the room-and-pillar method of mining is used. This method entails leaving 40-60 percent of the mineral in the ground to support the roof. Still, stability of these pillars is unpredictable, and it is not known whether they will deteriorate with time. This method may not be compatible with energy conservation policies. Also, leaving coal in the mine to protect the surface can produce fires, because subbituminous coal is conducive to spontaneous combustion.

Chapter 7

AIR QUALITY

Chapter Organizer: James Butler

Major Contributor: James Butler

As a result of the Clean Air Act of 1963 and its subsequent amendments, particularly the 1977 amendments, the problem of air pollution produced by mining has assumed a greater significance than it had in the past. Under the 1977 amendments, Federal Land Managers (FLM's), defined by law as the Secretary of Agriculture and the Secretary of Interior, are charged with insuring that users on Federal lands comply with National Ambient Air Quality Standards (NAAQS). In the case of National Forest System lands, the Secretary of Agriculture has delegated this authority to the Chief, who in turn has passed it to the Regional Forester. At the forest level, the Regional Forester will rely on input from the land manager, and in some cases the engineering staff, to make sure that mining operators have provisions in the operating plan to meet these standards.

POLLUTION IN MINING

What types of air pollutants does mining produce?

There are two major types of mining pollutants—particulates and gases. Particulates occur when the fine particles produced by mining disturbance are picked up and carried by the wind. The use of heavy equipment for extracting and transporting minerals results in high gaseous pollutant levels of carbon monoxide, nitrogen oxides, ozone, and sulfur dioxide, as well as some particulates. Of the two types of pollutants, particulates are by far the most important, because they are the most difficult to control.

Discussion:

Air pollution caused by mining may come from either point (stationary) or nonpoint (fugi-

tive) sources. Until recently, point sources have been considered to be smelter stacks, electric-generating plants burning fossil fuels, or other easily identifiable industrial operations. Now the trend is toward a broader definition, and what were once thought of as nonpoint sources are now considered point sources. Some examples are drilling operations, crushing and screening equipment, conveyors, and transshipment points for minerals.

Nonpoint sources are generally extensive and difficult to control. Pollution from nonpoint sources can result from activities such as blasting and hauling minerals over roads, as well as dust from tipples, mineral stockpiles, tailings, and waste dumps prior to mulching and/or revegetation.

It is important for the Forest Service engineer to determine whether air pollution is being discharged from a point or a nonpoint source. The Clean Air Act and State air-quality laws require permits before allowing the release of more than 250 tons/yr of pollutants from stationary point sources, other than those specifically mentioned in Section 169 of the Clean Air Act amendments of 1977.

What do National Ambient Air Quality Standards (NAAQS) consist of?

NAAQS are divided into primary standards, which protect the public safety and health, and do not consider the economics of attainment; and secondary standards, which protect the public welfare, vegetation, and wildlife, and do consider the economics of control.

Discussion:

To meet National Ambient Air Quality Standards, limitations are placed on six emissions: total suspended particulates, sulfur dioxide, ozone, nitrogen dioxide, lead, and carbon monoxide (table 3). Some States have also set emission standards for other particulates and gases.

What are air-quality areas?

The Clean Air Act established three categories of clean-air standards: Class I (The most restrictive), Class II (less restrictive), and Class III (the least restrictive). Every area in the country falls into one of these categories. There are also nonattainment areas, where NAAQS are exceeded for one or more emissions. Non-attainment areas can be declared in any one of the three classes.

Discussion:

The Act designates these areas as Class I: International parks, and national wilderness areas and national parks exceeding 5,000 acres. National parks larger than 6,000 acres that existed on the date the 1977 Clean Air Act amendments were passed may not be redesignated to a lower category.

The Act designated all other areas in the country as Class II or III. States may redesignate Class II areas as either Class I or Class III, but most States have few, if any, Class III areas. Instead, they have chosen to use the nonattainment status for metropolitan and industrial areas with high concentrations of pollution. All non-attainment areas must achieve NAAQS within

certain time frames. These schedules have to be approved by the Environmental Protection Agency (EPA), which is the Act's regulatory agency.

Units of Federal land larger than 10,000 acres that fall into the following categories are designated as Class II: all national forests and most Bureau of Land Management land. Some wilderness areas, because of prior land use, are also designated as Class II. All these areas can be upgraded to Class I; however, National Monuments, primitive areas, preserves, National Recreation Areas, wildlife areas, lakeshores, and seashores cannot be reduced to Class III.

The Forest Supervisor, with approval of State and local governments, can recommend that certain areas be redesignated as either Class I or Class III.

What is the Federal Land Manager's responsibility under the clean-air amendments?

The Federal Land Manager (Secretary of Agriculture) is charged with direct responsibility for and must take affirmative action to protect air-quality related values (including visibility) of Class I Air Quality Areas. This responsibility also applies to Class II areas.

Table 3. — Example of primary and secondary standards for sulfur dioxide and particulate matter

Pollutant	Primary standard	Secondary standard		PSD increments ¹ maximum allowable increase micrograms/m ³			Class I variances micrograms/m ³		
				165(d)(2)(C)(iv)			165(d)(2)(D)(iii)		
				Class I	Class II	Class III	low terrain	high ² terrain	
Sulfur dioxide	80 micrograms/m ³ - (0.03 parts/M) annual arithmetic mean	1,300 micrograms/m ³ - (0.5 parts/M) maximum 3 h concentration not to be exceeded more than once/yr	annual arithmetic mean	2	20	40	20	---	---
	365 micrograms/m ³ - (0.14 parts/M) maximum 24 h concentration not to be exceeded more than once/yr		24 h maximum	5	91	182	91	36	62
			3 h maximum	25	512	700	325	130	221
Particulate matter	75 micrograms/m ³ - annual geometric mean	60 micrograms/m ³ - annual geometric mean	annual geometric mean	3	19	37	19	---	---
	260 micrograms/m ³ - maximum 24 h concentration not to be exceeded more than once/yr	150 micrograms/m ³ - maximum 24 h concentration not to be exceeded more than once/yr	24 h maximum	10	37	75	37	---	---

¹Prevention of Significant Deterioration (PSD) Increments.

²High terrain is any area with an elevation of 900 ft or more above the base of the stack of the facility.

Discussion:

In reality, the Forest Service land manager is responsible for protecting air quality on Forest Service administered lands. When the forest engineering staff is assigned air-quality responsibilities, it will supply information to the land manager. Thus, when an operating plan is submitted, the engineering staff will review it to make sure that air-quality provisions have been included. If the plan does not appear to comply with air-quality standards, the staff should either request further data, or else recommend modification of the operating plan.

THE STATES' ROLE IN AIR QUALITY

Do the States have any responsibility for protecting air quality?

Each State is required by the Clean Air Act to pass air-quality laws equal to or more stringent than the Federal law, or else be faced with Federal regulation within the State by the EPA.

Discussion:

All States have now passed their own clean air laws and are proceeding through the next required step, the regulation phase, which involves preparation and approval of the State Implementation Plan (SIP). A SIP is the document that sets standards and guides States in managing their air resources. An engineer should be familiar with his State's SIP—it defines specific local air-quality regulations.

What information can be found in a SIP?

Each SIP contains plans for implementing, maintaining, and enforcing primary and secondary NAAQS as required by Federal law. Each State's SIP also notes its own particular regulations for listed air pollutants.

Discussion:

States have established State Air Quality Control Regions within Federal Air Quality Control Regions. Each State Air Quality Control Region designated in the SIP sets forth certain emission limitations and other measures designed to prevent significant deterioration of air quality. States have then divided their Air Quality Control Regions into Class I, II, III, or non-attainment areas. While setting emission limita-

tions for each class of air quality, States have established background baseline concentrations for the six NAAQS pollutants. Some States have also set emission standards for other particulates and gases. The States are bound by Federal regulations when setting up variances in emission standards. Presently, some variance is allowed only for sulfur dioxide and ozone.

DETERMINING AIR QUALITY

How does the engineer participate in determining the impact a mining operation will have on air quality?

The engineer will review the Environmental Assessment or Environmental Impact Statement for a proposed mining activity. Even when only a limited potential for gas or particulate emission exists, air-quality provisions must still fulfill National Environmental Policy Act requirements.

Discussion:

Few situations will require a State or Federal air-quality permits for premining activities. Care must be taken, however, to assure that any Class I areas near a single exploratory oil and gas or geothermal well are considered.

If mineral development takes place, the mining company will have to apply to the EPA or to the State if more than 100 tons/yr of emissions will occur from either a point or a nonpoint source, or if the emissions will exceed the NAAQS for the Air Quality Area. (The figure of 250 tons/yr of emissions mentioned previously is a standard for certain specified point source emissions. See Section 169 of the Clean Air Act amendments of 1977 for the specific list. The figure of 100 tons/yr is for those sources, point and nonpoint, that are not named specifically in the law.)

Should air quality appear to be a limiting factor, companies must gather as much data as possible, and if this information is still inadequate, must then set up monitoring stations to obtain further baseline air-quality information.

What happens if emissions cannot be held to State or Federal standards?

In this case, the company has three options: it can request variances in the emission

standards; the area may be redesignated from Class II to Class III, with the approval of the Forest Supervisor and local and State Governments; or the mining operator can acquire an existing company that already has an emission permit. If none of these steps is taken, the mining permit may be denied by the State or the EPA.

Discussion:

Regardless of the final outcome of the development, careful monitoring of baseline air quality is critical. The engineer should review the company's operating plan carefully, considering it in light of possible future expansion, reclamation and abandonment phases, and best available technology for emission control.

Additional Information:

For further information refer to:

"Amendments to Clean Air Act of 1963, Public Law 88-206," U. S. Govt. Printing Off., Serial No. 95-11. Nov. 1977.

"Clean Air Act of 1963, Public Law 88-206," U. S. Govt. Printing Off., 1963.

"Engineering and Design Manual—Coal Refuse Disposal Facilities," U. S. Dep. Inter., Mining Enforcement and Safety Admin.

"Environmental Impact of Mining," by C. G. Down and J. Stocks. Halsted Press, Division of John Wiley and Sons, New York. 1977.

"The Clean Air Act—An Analytical Discussion," by Neal Paulson and others. USDA For. Serv., Washington, D. C. Jan. 1978.

Chapter 8

RECLAMATION EQUIPMENT

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Mitigating environmental damage caused by mining must always be a prime consideration when reviewing a company's operating plan. Although the Forest Service engineer will not be directly involved in the reclamation process, familiarity with the equipment available for mined-land reclamation will help with engineering decisions that must be made during the review procedure.

Several steps are involved in mined-land reclamation, including soils/spoils shaping, fertilizing, mulching, and planting. Many types of reclamation equipment are available to help accomplish these tasks. This chapter provides an overview of such equipment; the machines described are just a few of the ones that have been used successfully in mined-land reclamation. For more detailed information about reclamation equipment, refer to the notes at the end of the chapter. Selection of equipment will depend on its availability and capability, and the characteristics of the site and treatment it requires.

CURRENTLY AVAILABLE EQUIPMENT

What special equipment is available for shaping land prior to reclamation?

Some machines commonly used to shape land for reclamation are the V-Plow, the Big Dude, and the Grader Bar.

Discussion:

These three machines, designed and constructed by the Bureau of Mines in cooperation with the Pittsburgh and Midway Mining Company, level or reshape large areas of spoil ridges that remain after surface mining. The first machine used in the process, the V-Plow, is a

V-shaped dozer blade on a large dozer, with a second dozer that pulls a heavy cable attached to the point of the V-Plow. The V-Plow can knock the tops off spoil ridges and make a fairly level bench, 30-40 ft wide.

The Big Dude is the next machine used in this process. The Big Dude is a 40-ft-wide dozer blade, which is pushed by one D-9 and pulled by another. This machine can move very large amounts of material—an average of 6,000 yd³/h—and it can level or reshape large areas of spoils.

The final machine used in this process is the Grader Bar, which is a normal type of dozer blade with low-height extensions added to each side, up to a total width of 30 ft. The Grader Bar does the final smoothing. After this step is complete, the area is ready for planting.

What machines are primarily used for fertilizing?

The Estes spreader is a machine often used in fertilization, although conventional manure spreaders may also be used.

Discussion:

The Estes spreader is essentially a large hopper mounted on a truck. It has an auger in the bottom of the hopper that carries material to the rear of the machine, where it is picked up by a fan and blown out on the land surface. It can be used to spread fertilizer and lime, as well as certain types of mulches such as wood chips.

What special equipment is used for seeding and mulching land for reclamation?

Many types of equipment are available for seeding and mulching, including: the Hodder gouger and the Bozeman Basin blade, the hydro-seeder, the Rangeland drill, the steep-slope scarifier-seeder, heavy duty disks, manure spreaders, and the rotovator. The Estes spreader, used for fertilizing, can also be used to spread certain types of mulch.

Discussion:

The Hodder gouger was designed and built to create small depressions in the soil to improve conditions for growing vegetation on reclaimed lands. The latest model is pulled behind a wheel tractor and, through a hydraulic cycling system, creates depressions in the soil surface that are about 2 ft long, 1 ft wide, and 8 in. deep. It also contains a seed box with tubes, which distributes a seed mixture into the depressions. This process creates better moisture conditions for vegetation and minimizes the adverse effects of wind. The Hodder gouger is used on slopes of 10 percent or less (fig. 10). The Bozeman Basin blade was designed to accomplish similar tasks, but the basins are much larger—8 ft wide, 15 ft long, and 2 ft deep. It is attached to the rear of a dozer and is used on slopes of up to 45 percent (fig. 11).

The hydroseeder is indispensable for certain land and climate conditions. It simultaneously applies a seed mixture, fertilizer, mulch, and a small amount of water. It is especially useful on steep slopes where conventional machinery cannot operate.

The Rangeland drill is a single-disk, deep-furrow drill with a high clearance, which has the advantage of being able to plant to greater depths in low-precipitation areas. It is useful on clay loam soils that have been previously tilled.

The steep-slope scarifier-seeder prepares seed-beds and plants seeds on very steep slopes, primarily above and below road fills or cuts. The machine is attached to the end of a hydraulic crane with an extendable boom.

Heavy-duty disks can be used for several purposes. Recently they have been used at some mined-land reclamation sites to incorporate

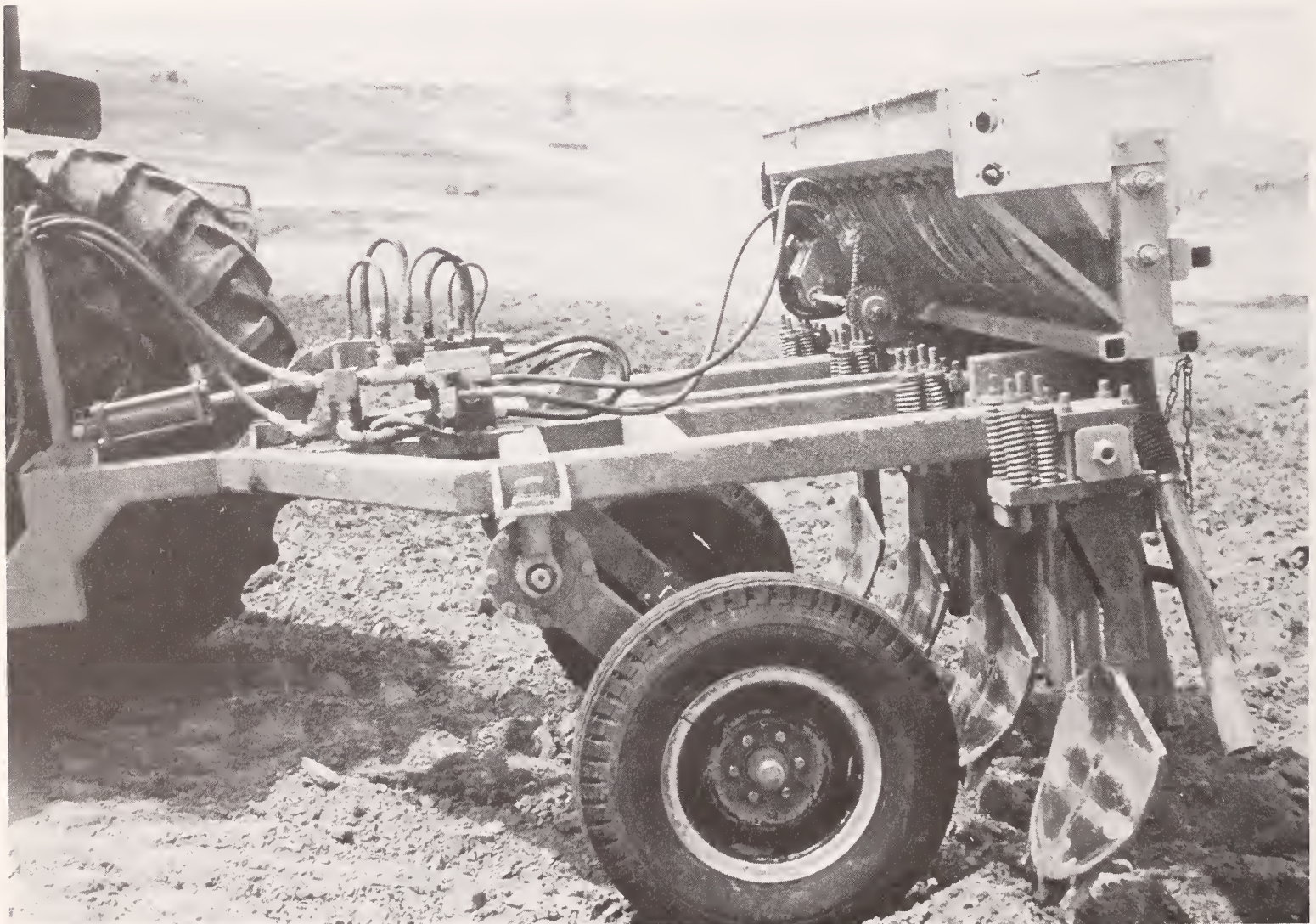


Figure 10. The Hodder gouger. (Donald Calhoun, U. S. Bureau of Land Management)

mulch or lime, and they can also be used to relieve compaction in the soil's surface layer.

Conventional manure spreaders have been modified so that they can become effective mulch spreaders. They can handle and distribute almost any type of mulch, including straw, hay, sludge, sawdust, and woodchips.

The rotovator is another machine that has been effective in incorporating mulch into the surface layer of the soil. It is useful in areas where rocks are neither too numerous nor too large.

What machines are used to plant on reclaimed lands?

The two machines mainly used to plant on reclaimed lands are the tree spade and the tree planter.

Discussion:

The tree spade is a tree-transplanting machine that was developed to establish clusters of trees and shrubs on mined-land reclamation sites. The tree spade can be mounted on a trailer, truck, or front-end loader. A special trailer has been developed for this machine that carries eight tree transplants at a time (fig. 12).

The tree planter, which has been used for many years in reforestation programs, has recently been used effectively to plant trees on reclamation sites.

Is there any reclamation equipment that needs to be improved?

Yes, improvements need to be made on machinery designed to collect native seeds.



Figure 11. The Bozeman Basin blade. (Donald Calhoun, U. S. Bureau of Land Management)

Discussion:

While some machines have been designed to collect native seeds, more work is needed in this area. Past efforts have included combine-type machines, truck-mounted vacuum-type machines, and backpack vacuum-type machines. It is felt that a more desirable native-seed collector would be a lightweight, vacuum-type machine that could be carried on bicycle wheels.

EQUIPMENT UNDER DEVELOPMENT

What are some future special-equipment needs for mined-land reclamation?

Some foreseeable equipment needs are for a bucket wheel excavator system with conveyor belts and stackers, a vertical mulcher, and a tubeling transplanter.

Discussion:

Bucket wheel excavators efficiently handle large volumes of overburden—currently 314,136 yd³ of material per day. They have been used in the United States on a limited basis and in Europe extensively (fig. 13). This system would be feasible if a surface mine was quite large and expected to operate for 100 or more years. A conveyor-belt system would need to be used in conjunction with the bucket wheel excavators, and conveyor belts that are up to 10 ft wide are now being used in Europe. They are mobile, maintenance free, have variable speeds, have a life expectancy of 20 years, and they can move enormous amounts of material. The third component of the system consists of a stacker, which takes the material from the conveyor belt and places it in the mined-out pit. With proper manipulation, the material can be placed back in



Figure 12. The tree spade. (Donald Calhoun, U. S. Bureau of Land Management)

the pit in the same relative profile location from which it came, and in such a way that little reshaping is necessary to achieve a useful land surface.

The vertical mulcher has already been used in some agricultural areas of the United States; it may also become a feasible approach to reclaiming areas where moisture penetration is a serious problem, such as at some sites mined for bentonite. It uses a ripper-tooth device behind a large dozer, with a hopper above the ripper tooth. The mulch is spread through the depth of the vertical space.

A tubeling transplanter would plant containerized plants with developed root systems in a planting medium on a reclaimed site intact. Tubeling transplanters would be especially useful where conditions are severe, such as with tail-

ings ponds, where there is low precipitation, or with vegetation that is difficult to establish.

Additional Information:

For more information on reclamation equipment, refer to "Handbook—Equipment for Reclaiming Strip Mined Land," by Darrell Brown. USDA For. Serv., Northern Region, Missoula, Mont. Feb. 1977.



Figure 13. A bucket wheel excavator. (Donald Calhoun, U. S. Bureau of Land Management)

APPENDIX A

GLOSSARY

Aquifer: A geologic formation or structure that transmits water. Aquifers are usually saturated sands, gravel, fractured rock, or cavernous rock.

Baseline data: Data gathered prior to mining for the purpose of outlining conditions existing on the undisturbed site. Reclamation success is measured against baseline data.

Clean Air Act of 1963 and subsequent amendments: This Act limits emissions through National Ambient Air Quality Standards (NAAQS). NAAQS consist of primary standards, which protect the public safety and health, and secondary standards, which protect public welfare, vegetation, and wildlife. The Act established three classes of air standards, Class I being the most restrictive, and each area in the country has been designated a class. When these standards cannot be met, an area may be classified as a nonattainment area.

Clean Air Act 1977 amendments: Under the 1977 amendments, Federal Land Managers (Secretary of Agriculture and Secretary of Interior) are responsible for making sure that users of Federal lands comply with NAAQS.

Core: The sample of rock obtained through the use of a hollow drilling bit, which cuts and retains a section of the rock penetrated.

Dump: Also called fill, backfill, spoils pile, waste-disposal area, or storage site. An area where overburden is piled during the mining process, either temporarily or permanently.

Environmental Assessment (EA) (Replaced the EAR): An analysis of all actions and their predictable short- and long-term environmental effects, which include physical, biological, economic, and social factors and their interactions. Also, a concise public document required by the regulations for implementing the procedural requirements of the National Environmental Policy Act of 1969 (NEPA).

Environmental Impact Statement (EIS): A document prepared by a Federal agency in which anticipated environmental effects of a planned course of action or development are evaluated, as prescribed by the National Environmental Policy Act of 1969 (NEPA).

Erosion: The group of physical and chemical processes whereby earth or rock material is worn away, loosened, or dissolved and removed from any part of the earth's surface. It includes the processes of weathering, solution, corrosion, and transportation.

Exploration: The search for economic deposits of minerals, ore, gas or oil, or coal, through the practices of geology, geochemistry, geophysics, drilling, shaft sinking, and mapping.

Feasibility study: Analysis of the rate of return that can be expected from the mine at a certain rate of production. Based on this study, the decision to develop the ore body may be made.

Forest plan: According to Forest Service regulations, each forest must have a forest plan, which outlines the most desired and alternative land uses for that site.

Geotechnical engineering: A branch of engineering that is essentially concerned with the design aspects of slope stability, settlement, earth pressures, bearing capacity, seepage control, and erosion.

Ground water: Water within the earth that is in the zone of saturation where all openings in soils and rocks are filled—the upper surface of which forms the water table; water that supplies wells and springs.

Impoundment: The accumulation of any form of water in a reservoir or other storage area.

Infiltration: The movement of water into the soil through pores or other openings.

Interdisciplinary team (ID team): A team composed of Forest Service personnel who collectively represent specialized areas of technical knowledge about natural-resource management applicable to the area being planned. The team will consider problems collectively, rather than separating them along disciplinary lines. This interaction will insure systematic, integrated considerations of physical, biological, economic, and social sciences and design arts.

Land-management plan: See forest plan.

Leaching: The removal of soluble constituents from a substance by the action of a percolating liquid.

Mine-waste disposal embankment: An earth and rock structure that encloses mining waste materials. Also see Dump.

Mineral beneficiation: The process of treating ore so that the resulting product is richer or more concentrated with minerals. It is primarily a milling and concentrating process.

Mining plan: See operating plan.

Monitoring: The careful observation and sampling of an activity to insure that the design objectives are being met.

Mulching: Placing or leaving nonliving material on or near the soil surface for the purpose of protecting the surface from erosion or protecting plants from heat, cold, or drought.

National Ambient Air Quality Standards (NAAQS): See the Clean Air Act of 1963 and subsequent amendments.

Native species: Plants that originated in the area in which they are found; i.e., they naturally occur in that area.

Nonattainment area: See the Clean Air Act of 1963 and subsequent amendments.

Nonpoint air pollution: Pollution caused by sources that are nonstationary. In mining, nonpoint air pollution results from such activities as blasting and hauling minerals over roads, as well

as dust from tipples, mineral stockpiles, tailings, and waste dumps prior to mulching and/or revegetation.

Operating plan: Submitted by the mining operator, the operating plan outlines the steps the mining company will take to mine and rehabilitate the site. The operating plan is submitted prior to starting mining operations. For the purpose of this guide, the term operating plan is used synonymously with the term mining plan.

Overburden: Material overlying a deposit of useful materials, ores, or coal.

Performance bond: A bond of liability placed on a mining company. The bond specifies regulations for determining the acceptability of certain mining and reclamation activities.

Phreatic water line: The top of the free-water surface within the body of a dam or tailings embankment.

Piezometer: A pressure measuring instrument used either to locate the elevation and slope of the phreatic surface or to measure the hydraulic head of confined water.

Point air pollution: Pollution that results from stationary sources. In terms of mining, some examples of point sources are drilling operations, crushing and screening equipment, conveyors, and transshipment points for minerals.

Preliminary site reconnaissance: A site-specific survey that takes place before decisions are made that affect land allocation for a particular activity. It includes investigation of such items as terrain, slope, drainage crossings, hydrology, and vegetation.

Reclamation: Returning disturbed land to a form and productivity that will be ecologically balanced and in conformity with a predetermined land-management plan.

Rehabilitation: See reclamation.

Safety factor: A safety factor is a ratio of resisting forces to driving forces. By determining a structure's safety factor, a numerical index of stability is obtained.

Sediment: Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment basin: A pond, depression, or other device used to trap and hold sediment.

Slumping: A sudden sliding or sinking of the slopes of a mine dump, generally caused by excess water in the dump or foundation.

Soil: The loose surface material of the earth, usually consisting of disintegrated rock and a mixture of organic matter and soluble salts.

Spoils: Any dirt or rock that has been removed from its original location by mining operations.

Spoils dump: See dump.

State Implementation Plan (SIP): A document that sets standards and guides States in managing their air resources. It defines specifically local air-quality regulations, and contains plans for implementing, maintaining, and enforcing primary and secondary National Ambient Air Quality Standards as required by Federal law.

Stockpiling: Storage of material for later use.

Stripping ratio: The number of units of unpayable material that must be mined to expose one unit of ore.

Subsidence: A local lowering of surface land caused by the collapse of rock and soil into an underground void; it can result in stability failures such as landslides and mine-roof cave-ins.

Surface runoff: The moisture that is not absorbed by the soil.

Tailings: The waste material that remains after the valuable minerals have been removed from raw materials by milling.

Tailings sites: Areas, including embankments

and ponds, retaining the fine waste from milling operations.

Talus slope: A natural slope formed by the accumulation of rocks and rock debris at the base of a steep rock face.

Watershed: The total area above a given point on a stream that contributes water to the flow at that point.

Water table: The upper surface of the ground water or that depth below which the soil is saturated with water.

APPENDIX B

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 - Standards for, structure, 17
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1979. User guide to engineering. USDA For. Serv. Gen. Tech. Rep. INT-70, 58 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Summarizes and discusses key questions and rules the engineer should consider when working in mining area reclamation. Topics include preliminary site reconnaissance; computer-aided planning tools; transportation systems; minerals exploration and development facilities; geotechnical engineering and mining practices; mass stability; air quality; and reclamation equipment.

KEYWORDS: engineering, mining, operating plan, transportation facilities, geotechnical practices, air quality, mass stability.

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THE SEAM PROGRAM

The Surface Environment and Mining Program, known as SEAM, was established by the Forest Service to research, develop, and apply new technology to help maintain a quality environment while helping meet the Nation's mineral requirements. SEAM is a partnership of researchers, land managers, mining industries, universities, and political jurisdictions at all levels.

Although the SEAM Program was assigned to the Intermountain Station, some of its research projects were administered by the Rocky Mountain and Pacific Southwest Research Stations.

MINERAL USER GUIDES

Other User Guides for specialists involved in minerals activities are:

- User Guide to Vegetation, Gen. Tech. Rep., INT-64
- User Guide to Soils, Gen. Tech. Rep., INT-68
- User Guide to Sociology and Economics, Gen. Tech. Rep., INT-73
- User Guide to Hydrology, Gen. Tech. Rep., INT-74
- User Guide for Wildlife (planned)
- User Guide for Visual Management (to be published as part of the National Forest Landscape Management Series)

To obtain copies of these guides, write: Intermountain Forest and Range Experiment Station, USDA Forest Service, 507 25th St., Ogden, UT 84401.

